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Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the

GRAIN PROCESSING

Segment of the Grain Mills

Point Source Category

MARCH 1974

U.S. ENVIRONMENTAL PROTECTION AGENCY
Washington, D.C. 20460

DEVELOPMENT DOCUMENT

for

EFFLUENT LIMITATIONS GUIDELINES

and

NEW SOURCE PERFORMANCE STANDARDS

for the

GRAIN PROCESSING SEGMENT OF THE

GRAIN MILLS POINT SOURCE CATEGORY

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ABSTRACT

This document presents the findings of an extensive study of the grain milling industry by the Environmental Protection Agency for the purpose of developing effluent limitations guidelines, Federal standards of performance, and pretreatment standards for the industry, to implement Sections 304, 306, and 307 of the "Act."

Effluent limitations guidelines contained in this document set forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best available technology economically achievable which must be achieved by existing point sources by July 1, 1977 and July 1, 1983, respectively. The Standards of Performance for new sources contained herein set forth the degree of effluent reduction which is achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives.

Separate effluent limitations guidelines are described for the following subcategories of the grain milling point source category; corn wet milling, corn dry milling, normal wheat flour milling, bulgur wheat flour milling, normal rice milling, and parboiled rice processing. Treatment technologies are recommended for the four subcategories with allowable discharges: corn wet milling, corn dry milling, bulgur wheat flow milling, and parboiled rice processing. They are generally similar, and may include equalization, and biological treatment followed by clarification. In order to attain the 1983 limitations additional solid removal techniques will be necessary. The standards of performance for new sources are the same as the 1983 limitations.

The cost of achieving these limitations are described. The highest costs are in the corn wet milling subcategory. For a typical corn wet milling plant with a grind of 60,000 bu/day, the investment cost for the entire treatment system to meet the 1977 limitations is $2,544,000. An additional $288,000 will be necessary to install the solids removal techniques to meet the 1983 standards. The economic impact of the proposed effluent limitations guidelines and standards of performance are contained in a separate report entitle "Economic Analysis of Proposed Effluent Guidelines-GRAIN MILLING INDUSTRY."

Supportive data and rationale for developments of the proposed effluent limitations guidelines and standards of performance are contained in this report.

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CONCLUSIONS

The segment of the grain milling industry that is covered in this document (Phase I) has been classified into six subcategories. This categorization is based on the type of grain and manufacturing process. Available information on factors such as age and size of plant, product mix, and waste control technologies does not provide a sufficient basis for additional subcategorization.

The subcategories of the grain milling industry are as follows:

1. Corn wet milling
2. Corn dry milling
3. Normal wheat flour milling
4. Bulgur wheat flour milling
5. Normal rice milling
6. Parboiled rice processing

SECTION II

RECOMMENDATIONS

The recommended effluent limitations for the waste water parameters of significance are summarized below for the subcategories of the grain milling industry covered in this document. These values represent the maximum average allowable loading for any 30 consecutive calendar days. Excursions above these levels should be permitted with a maximum daily average of 3.0 times the average 30-day values listed below.

The effluent limitations to be achieved with the best practicable control technology currently available are as follows:

	BOD		Suspended Solids		pH
	kg/kkg	lbs/MSBu	kg/kkg	lbs/MSBu	
Corn wet milling	0.893	50.0	0.893	50.0	6-9
Corn dry milling	0.071	4.0	0.062	3.5	6-9
Normal wheat flour milling		no discharge of process wastes			
Bulgur wheat flour milling	0.0083	0.5	0.0083	0.5	6-9
Normal rice milling		no discharge of process wastes			
Parboiled rice milling	0.140	0.014	0.080	0.008	6-9

Using the best available control technology economically achievable the effluent limitations are:

	BOD		Suspended Solids		pH
	kg/kkg	lbs/MSBu	kg/kkg	lbs/MSBu	
Corn wet milling	0.357	20.0	0.179	10.0	6-9
Corn dry milling	0.0357	2.0	0.0179	1.0	6-9
Normal wheat flour milling		no discharge of process wastes			
Bulgur wheat flour milling	0.0050	0.3	0.0033	0.2	6-9
Normal rice milling		no discharge of process wastes			
Parboiled rice milling	0.070	0.007	0.030	0.003	6-9

The recommended new source performance standards correspond, in all instances, to the limitations defined above for the best available control technology economically achievable.

SECTION III

INTRODUCTION

PURPOSE AND AUTHORITY

Section 301(b) of the Act requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best practicable control technology currently available as defined by the Administrator pursuant to Section 304(b) of the Act. Section 301(b), also, requires the achievement by not later than July 1, 1983, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best available technology economically achievable which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b) of the Act. Section 306 of the Act requires the achievement by new sources of a Federal standard of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants.

Section 304(b) of the Act requires the Administrator to publish within one year of enactment of the Act, regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedure innovations, operation methods and other alternatives. The regulations proposed herein set forth effluent limitations guidelines pursuant to Section 304(b) of the Act for the grain milling source category.

Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306(b) (1) (A) of the Act, to propose regulations establishing Federal standards of performances for new sources within such categories. The Administrator published in the Federal Register of January 16, 1973 (38 F. R. 1624), a list of 27 source categories. Publication of the list constituted announcement of the Administrator's intention of establishing, under Section 306, standards of performance applicable to new sources within the grain milling source category, which was includedd within the list published January 16, 1973.

SUMMARY OF METHODS USED FOR DEVELOPMENT OF THE EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS OF PERFORMANCE

The effluent limitations guidelines and standards of performance proposed herein were developed in the following manner. The point source category was first categorized for the purpose of determining whether separate limitations and standards are appropriate for different segments within a point source category. Such subcategorization was based upon raw material used, product produced, manufacturing process employed, and other factors. The raw waste characteristics for each subcategory were then identified. This included an analysis of (1) the source and volume of water used in the process employed and the sources of waste and waste waters in the plant; and (2) the constituents (including thermal) of all waste waters including toxic constituents and other constituents which result in taste, odor, and order, and color in water or aquatic organisms. The constituents of waste waters that should be subject to effluent limitations guidelines and standards of performance were identified.

The full range of control and treatment technologies existing within each subcategory was identified. This included an identification of each distinct control and treatment technology, including both inplant and end-of-process technologies, which are existent or capable of being designed for each subcategory. It also included an identification in terms of the amount of constituents (including thermal) and the chemical, physical, and biological characteristics of pollutants, of the effluent level resulting from the application of each of the treatment and control technologies. The problems, limitations and reliability of each treatment and control technology and the required implementation time was also identified. In addition, the nonwater quality environmental impact, such as the effects of the application of such technologies upon other pollution problems, including air, solid waste, noise and radiation were also identified. The energy requirements of each of the control and treatment technologies were identified as well as the cost of the application of such technologies.

The information, as outlined above, was then evaluated in order to determine what levels of technology constituted the "best practicable control technology currently available," "best available technology economically achievable" and the "best available demonstrated control technology, processes, operating methods, or other alternatives." In identifying such technologies, various factors were considered. These included the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application, the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques, process changes, nonwater quality environmental impact (including energy requirements,) and other factors.

SOURCES OF DATA

The data for identification and analyses were derived from a number of sources. These sources included published literature, previous EPA technical publications on the industry, a voluntary information retrieval form distributed to the Corn Refiners Association and to other grain millers, information contained in Corps of Engineers discharge permit applications, and on-site visits, interviews, and sampling programs at selected grain milling facilities throughout the United States. A more detailed explanation of the data sources is given below. All references used in developing the guide lines for effluent limitations and standards of performance for new sources reported herein are included in Section XIII of this document.

During this study the trade associations connected with the grain milling subcategories covered by this study were contacted. These associations are listed below:

Milling subcategory	Association
Wet Corn	Corn Refiners Association, Inc.
Dry Corn	American Corn Millers Federation
Normal Wheat Flour	Millers National Federation Assoc. of Operative Millers National Soft Wheat Millers Association
Bulgur Wheat Flour	Protein Cereal Products Institute
Rice, Normal & Parboiled	Rice Millers Association

These associations were informed of the nature of the study and their assistance was requested. Subsequently, a voluntary data retrieval form was made available to them and, also, to individual plants. This form is shown on the following pages. The completed forms provided a more detailed source of information about the various plants including manufacturing processes, data on raw materials and finished products, waste characterization and sources, waste treatment, and water requirements. All of the existing plants in the corn wet milling, bulgur wheat flour milling, and rice milling subcategories were covered. Based on the 1971 Directory of the Northwestern Millers there are 126 corn dry mills listed. The plants contacted comprise 70-75 percent of corn processed by the corn dry milling industry. An unknown percent of the normal wheat flour milling industry was contacted. A summary of the plants who responded and those forms with usable data are shown below.

EPA EFFLUENT LIMITATIONS GUIDELINE STUDY
OF THE GRAIN MILLING INDUSTRY

by

Sverdrup & Parcel and Associates, Inc.

Information Retrieval Guide

February, 1973

I GENERAL

- A. Company name
- B. Corporate address
- C. Corporate contact
- D. Address of plant reporting
- E. Plant contact

II MANUFACTURING PROCESS CHARACTERIZATION (Separate sheet for each process, i.e., corn wet milling, wheat milling, etc.)

- A. Manufacturing process pertinent to this study
- B. Other processes at this plant
- C. Products
- D. Plant capacity
    1. Annual raw material processed
    2. Average daily raw material processed
- E. Operating schedule (hours/day and days/year)
- F. Number of employees
- G. Age of plant

III WATER REQUIREMENTS

- A. Volume and sources

B. Uses (including volumes)

1. Process
2. Grain washing
3. Cooling
4. Boilers
5. Plant cleanup
6. Sanitary
7. Other

C. Available information on raw water quality

D. Water treatment provided

1. Volume treated
2. Describe treatment system and operation
3. Type and quantity of chemicals used

E. Available information on treated water quality

IV PROCESS WASTEWATER

A. Volumes and sources

B. Does the source, volume, or character of the wastewater vary depending on the type or quality of product?

C. How do wastewater characteristics change during start-up and shutdown as compared to normal operation?

D. Available data on characteristics of untreated wastewaters from individual sources and combined plant effluent. (Not just single average numbers, but actual data on weekly or monthly summaries).

1. pH
2. BOD

3. COD
4. Suspended solids
5. Dissolved solids
6. Total solids
7. Temperature
8. Alkalinity and acidity
9. Phosphorus
10. Chlorides
11. Sulfates
12. Oil and grease
13. Other (all available information should be collected)

E. Wastewater treatment

1. Identify wastewater sources and volumes going to treatment facility
2. Reason for treatment
3. Describe treatment system and operation
4. Type and quantity of chemicals used, if any
5. Available data on treated wastewater quality (Same items as in Section III. D. above)
6. Describe any operating difficulties encountered
7. Results of any laboratory or pilot plant studies
8. Known toxic materials in wastewater

F. Wastewater recycle

1. Is any wastewater recycled presently?
2. Can wastewater be recycled? What are the restraints on recycling?

G. In-plant methods of water conservation and/or waste reduction

H. Identify any air pollution, noise, or solid wastes resulting from treatment or other control methods. How are solid wastes disposed of?

I. Cost information related to water pollution control
  1. Treatment plant and/or equipment and year of expenditure
  2. Operation (personnel, maintenance, etc.)
  3. Power costs
  4. Estimated treatment plant and equipment life

J. Water pollution control methods being considered for future application

V COOLING WATER

A. Process steps requiring cooling water

B. Heat rejection requirements (Btu/hour)

C. Type of cooling system, i.e., once-through or recirculating

D. Cooling tower
  1. Recirculating flow rate
  2. Blowdown rate
  3. Type and quantity of chemicals used
  4. Blowdown water quality

E. Once-through water quality
  1. Flow rate
  2. Type and quantity of chemicals used
  3. Discharge water temperature

VI BOILER

A. Capacity

B. Blowdown flow rate and characteristics

Industry	Retrieval Forms Returned	Retrieval Forms Returned with Usable Data
Corn Wet Milling	16	15
Corn Dry Milling	9	4
Wheat Milling	47	20
Bulgur Milling	6	2
Rice Milling:	29	9
Ordinary Process	28	8
Parboiled Process	5	2

RAPP applications to the Corps of Engineers for discharges together with computerized RAPP data, supplied by EPA, were also used as a source of data. These data included the identification of the plant, the number of waste discharge points, the volumes of discharge, and the character and quantity of waste. The number of sources included in the RAPP applications was seven in the corn wet milling industry, two in the normal wheat milling industry, and one in the parboiled rice industry.

Plant visits provided information about the manufacturing process, the distribution of water, sources of wastes, type of equipment used, control of water flows, in-plant waste control, and effluent treatment. A total of eleven plants were visited in the following subcategories:

Industry	Total Plants Visited
Corn Wet Milling	5
Corn Dry Milling	1
Normal Wheat Flour	1
Bulgur Wheat Flour	1
Parboiled Rice	3

In addition to the above, several plants in each category were contacted by telephone for information on the industry and waste handling. Detailed data were obtained during these conversations consisting of raw material description, flow rates, waste quantities, and waste treatment.

Plant sampling of each industry subcategory was provided at a total of eight plants with emphasis focused on plants having typical waste loads and waste treatment facilities. The sampling program provided data on the raw and treated waste streams. It also provided verification of data on waste water characteristics provided by the plants.

Industy	Total Plants Sampled
Corn Wet Milling	4
Corn Dry Milling	1
Bulgur Milling	1
Parboiled Rice Milling	2

GENERAL DESCRIPTION OF THE INDUSTRY

The cultivation, harvesting, and milling of grains dates back to the beginning of recorded history. Wheat was first cultivated in Asia, later became prominent in Europe, and was introduced to the United States by the colonists in the early 1600's. Similarly, rice originated in Asia thousands of years ago and was brought to this country in the mid 1600's. Corn or maize is the only one of the three major cereal grains that is indigenous to this country, and was cultivated by the Indians long before Columbus discovered America.

The cereal grains, so-called because they can be used as food, include barley, corn, grain sorghum, millet, oats, rice, rye, and wheat. This report, however, only covers the milling of the three principal grains, namely, corn, wheat, and rice.

Corn

With an annual agricultural yield of about 140 million metric tons (5.5 billion bushels), the United States is easily the largest corn producer in the world. About 80 percent of the corn crop is used as animal feed, as shown in the accompanying table. Some eight percent of the corn is milled into various products and the remainder of the crop is used for table and breakfast foods, alcohol, and other industrial products or is exported.

Table 1

Uses of Corn Grown in the United States

	Percent of total corn production
Feed	77.3
Export	14.0
Wet milling	5.7
Dry milling	2.2
Alcohol	0.8
Seed	0.3
Breakfast food	0.2

Corn is milled by either dry or wet processes, and the production methods and final products of each are distinctly different. Corn dry milling produces meal, grits, and flour while the principal products of corn wet milling are starch, oil, syrup, and dextrose.

Corn Wet Milling

The corn wet milling industry is an American development and originated with the commercial extraction of starch from corn in 1842, at a time when the greatest source of starch was from wheat and potatoes. Starch from the corn wet milling process now accounts for 95 percent of the American starch output.

The first corn wet mills were segregated to produce either finished starch or corn syrup. Not until the turn of the century was a combined mill developed to produce both starch and syrup. Many of the present milling companies had their beginning at about this time as most of the existing milling plants were consolidated.

Today, twelve companies operate 17 plants in seven states with a total corn grind of over seven million metric tons per year (275 million bushels per year). A list of the companies and plants is given in Table 3. Of these plants, eight were put into operation since 1949, utilizing newly developed equipment and methods of operation to provide better products, higher yields, and less waste. The older plants meanwhile, have incorporated new process procedures and replaced nearly all equipment with more efficient machinery providing cleaner operating conditions and increased yields with reduced odors, wastes, and water usage. The raw material for corn wet milling is the whole kernel. Most of the grain, primarily hybrid yellow dent corn, comes from the midwest or Corn Belt region of the country. The composition of yellow dent corn is given in Table 2.

Table 2

Composition by Dry Weight of Yellow Dent Corn

	Percent
Carbohydrates	80
Protein	10
Oil	4.5
Fiber	3.5
Ash	2.0

The standard unit of measure of corn in the United States is the bushel (25.4 kg) and plant size is measured by the number of bushels of corn processed per day. Wet milling plants receive the corn kernels at 10 to 25 percent moisture. The standard bushel is defined, for purposes of this report, as 25.4 kg (56 lbs) corn at 15.5 percent moisture. The 17 corn wet mills in this country range in size from about 380 to 3050 kkg/day (15,000 to 120,000 SBu/day).

Table 3

Corn Wet Milling Companies and Plants

American Maize-Products Company
250 Park Avenue
New York, New York 10017
Plant: Hammond, Indiana 46326

Anheuser-Busch, Inc.
P.O. Box 1810 Bechtold Station
St. Louis, Missouri 63118
Plant: Lafayette, Indiana 47902

Cargill, Inc.
Cargill Building
Minneapolis, Minnesota 55402
Plants: Dayton, Ohio 45414
Cedar Rapids, Iowa 52401

Clinton Corn Processing Company
Division of Standard Brands, Inc.
Clinton, Iowa 52732
Plant: Clinton, Iowa 52732

Corn Sweeteners, Inc.
P.O. Box 1445
Cedar Rapids, Iowa 52406
Plant: Cedar Rapids, Iowa 52406

CPC International Inc.
International Plaza
Englewood Cliffs, New Jersey 07632
Plants: Argo, Illinois 60501
Pekin, Illinois 61555
North Kansas City, Missouri

Corpus Christi, Texas 78048

Dimmitt Corn Division
Amstar Corporation
Dimmitt, Texas 79027
Plant: Dimmitt, Texas
79027

Grain Processing Corporation
Muscatine, Iowa
Plant: Muscatine, Iowa 52761

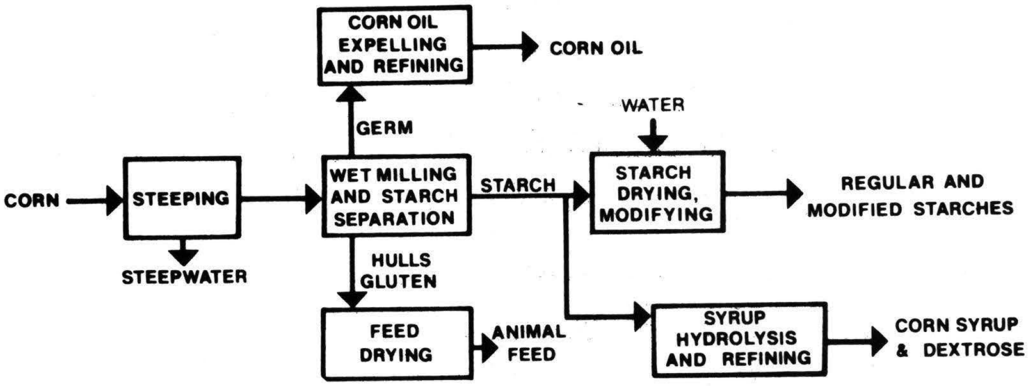
The Hubinger Company
Keokuk, Iowa 52632
Plant: Keokuk, Iowa 52632

National Starch and Chemical Corporation
750 Third Avenue
New York, New York 10017
Plant: Indianapolis
Indiana 46206

Penick and Ford, Limited
(Subsidiary of VWR United Corporation)
Cedar Rapids, Iowa 52406
Plant: Cedar Rapids, Iowa

A. E. Staley Manufacturing Company
Decatur, Illinois 62525
Plants: Decatur, Illinois
62525
Morrisville, Pennsylvania 19067

The corn wet milling can be considered as three basic process operations, namely milling, starch production and syrup manufacturing as shown in the accompanying schematic diagram. The initial wet milling sequence separates the basic components of the corn kernel into starch, germ, gluten, and hull. The individual process operations include steeping, grinding, washing, screening, centrifugation, and flotation. Following the basic milling and separation operations, the product slurry may be dried, modified and then dried, or converted to corn syrup or dextrose. In processing the starch slurry from the wet milling operations, the fractions are proportioned between the starch finishing and corn sweeteners departments. The supply of starch distributed to each will depend on daily and seasonal fluctuations controlled by the economic situation and, ultimately, customer demand and competition. Products from the dry starch operations may be classified as regular (unmodified) and modified starches. The purpose of modification is to change the resultant starch characteristics to conform to the specific needs of the industry using the product. Starch modifications are accomplished, generally, by chemically treating the raw starch slurry under closely controlled conditions. In the corn sweetener department, the starch slurry is hydrolyzed to corn syrup and dextrose.



CORN WET MILLING

The finished products of starch and corn sweeteners resulting from the corn wet milling process, as well as the secondary products, have many uses in the home and industry. A portion of the finished products are used directly in the home, but the bulk of the products are distributed among industrial users. Food products account for 1/4 to 1/3 of the total starch and starch converted products. The list of industrial uses includes, in descending order of quantity: paper products, food products, textile manufacturing, building materials, laundries, and other miscellaneous applications.

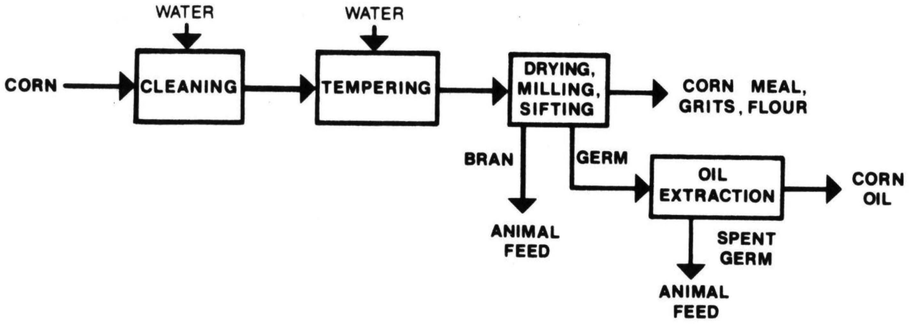
Corn Dry Milling

Corn dry milling differs in almost all respects from wet milling, except in the raw material used. The grinding or dry milling of corn predates wet milling by hundreds of years. Today, a little over two percent of the total corn production is processed by the dry millers.

There are, approximately, 126 corn dry mills throughout the country, although most are located in the midwestern Corn Belt, ranging in size from very small millstone operations to large modern mills with capacities up to about 1500 to 1775 kkg/day (60,000 to 70,000 SBu/day.) The larger plants process about 90 percent of the corn in the dry milling segment of the industry.

Most small millers are distinguished from the larger plants in both production methods and finished products. Specifically, the small mills usually grind the whole kernel and produce only ground whole corn meal. These small mills use little, if any, water and will not be discussed further in this report.

The larger mills employ a number of production steps designed to separate the various fractions of the corn, namely the endosperm, bran, and germ. The primary production sequence is shown on the accompanying diagram. The corn is first cleaned and then tempered to a moisture content of about 21 percent. The germ and bran are separated from the endosperm in a series of grinding, sifting, classifying, and aspirating operations. In an additional step, corn oil is mechanically extracted from the germ. The final products of a typical corn dry mill include corn meal, grits, flour, oil, and animal feed.



CORN DRY MILLING

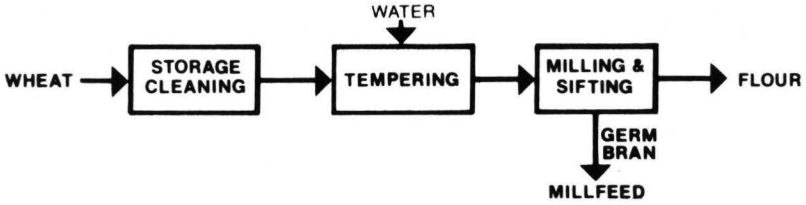
Wheat

Wheat production is now the largest of any cereal grain in the world. The United States produces about 38 million metric tons (1.5 billion bushels) and is second only to Russia in total production. In this country, about 40 percent of the wheat is milled into flour and the remainder is used for breakfast foods, macaroni products, animal feed, alcohol production, and other more limited markets.

The milling of wheat in the United States is handled by over two hundred plants of various sizes and ages, scattered across the country. There are several types of wheat and various grades of each type available to the wheat miller. In some mills, other grains are milled using similar operations. Different kinds of wheat or regulated blends of wheat are mixed at the mills, together with various additives. These products are formulated to customer specifications to meet the required qualities for final use.

Preparation of wheat into ground flour or granular products is fundamentally a dry milling process. Other similar grains such as rye and durum, not detailed separately in this report, are milled by comparable processes. Some variations may be found in the cleaning process and in the milling and separation based on the prime product requirements.

Wheat milling, shown below, begins with cleaning with water or air. The wheat is then tempered to about 17 percent moisture and milled in roller mills. The germ and bran are separated from the flour by sifting.



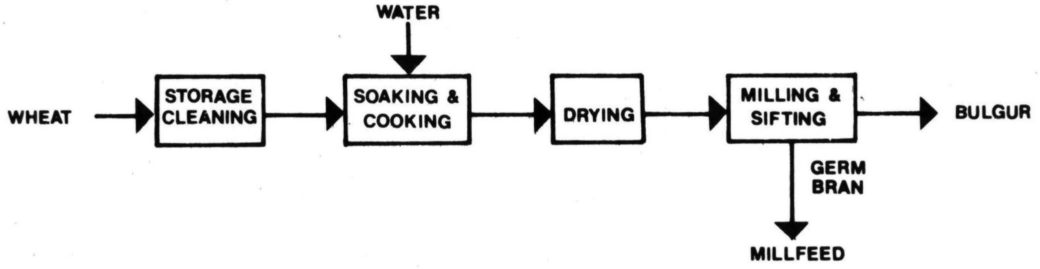
WHEAT MILLING

A special process of particular significance to this study, is the production of bulgur shown in the next diagram. Bulgur is wheat that is parboiled, dried, and partially debranned for use in either cracked or whole grain form. Bulgur is produced primarily for the Federal Government as part of a national effort to utilize surplus wheat for domestic use and for distribution to underdeveloped countries as part of the Foods for Peace program. There are five bulgur mills in this country ranging in size from about 145 to 408 kkg/day (3200 to 9000 cwt/day). The companies, plant locations, and estimated capacities are given in Table 4.

Table 4

Bulgur Mills - Locations and Estimated Capacities

Company and plant location	Estimated capacity kkg/day	Estimated capacity cwt/day
Archer Daniels Midland Co. Shawnee Mission, Kansas 66207 Plant: Abilene, Kansas	227	5000
Burrus Mills Division Cargill, Inc. Dallas, Texas 75221 Plant: Dallas, Texas	145	3200
California Milling Corporation Los Angeles, California 90058 Plant: Los Angeles, California	204	4500
Fisher Mills, Inc. Seattle, Washington 98134 Plant: Seattle, Washington	408	9000
Lauhoff Grain Company Danville, Illinois 61832 Plant: Crete, Nebraska	272	6000



BULGUR PRODUCTION

Rice

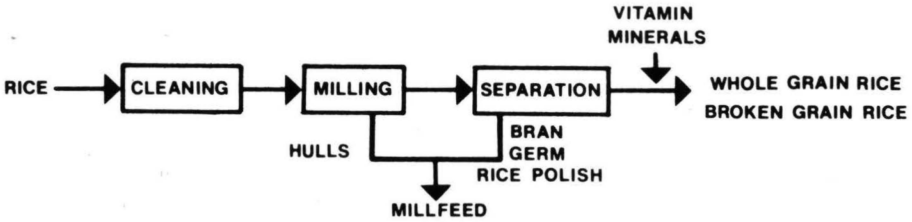
The unique nutritional and chemical qualities of rice makes it one of the world's most important food products. In the United States, it is used in numerous products and in many forms including (in descending order):

Direct table food
Brewing
Breakfast cereals
Soups, canned foods, baby foods
Crackers, candy bars, and others

Production of rice is scattered throughout the world with the greatest crop concentration in Asia and nearby island areas. Although the United States produces only a small percentage of the total crop, it is the world's largest exporter. The cultivation of rice in the United States began around 1635 in South Carolina. Rice is now produced in thirteen states with an annual grain production over 3.8 million metric tons in 1972 (8.5 billion pounds). Texas, Arkansas, Louisiana, and California produce 97 percent of this total. There has been a gradual decline in the number of rice companies, and a corresponding decline in the number of mills operated. In 1973 there were 36 companies in the United States operating 42 mills.

Milling of rice differs from other cereal milling in that the product is the whole grain rather than flour or meal. The milling sequence, shown in the accompanying diagram, begins with the cleaning of the rough rice and removing the inedible hulls by passing the grain through shelling devices or hullers. Aspirators then separate the loosened hulls from the resultant brown rice which, in turn, is milled to remove the coarse outer layers of bran and germ using machines called pearlers. The bran and germ are separated from the milled rice and the final white rice product is sized, enriched with vitamins and minerals, and packaged. Rice hulls, bran, polish, and small pieces of the grain may be sold separately or combined into so-called millfeed for animals. The average yields for ordinary rice milling are:

	Percent
Whole grain white rice	54
Broken grain rice	16
Hulls and waste	20
Bran	8
Rice polish	2



ORDINARY RICE MILLING

Parboiling rice has been practiced in foreign countries for years and differs significantly from ordinary rice milling. The manufacturing process was introduced in the United States in 1940. At present, there are six known parboiled rice plants in this country, as given in Table 5, four in Texas, one in Arkansas, and one in California. The purpose of parboiling rice is to force some of the vitamins and minerals from the bran into the endosperm. The product, also, has superior cooking qualities and is more impervious to insect damage in storage.

The manufacturing process, shown below, begins with careful cleaning of the rice. The rice is then parboiled by soaking in water and cooking to gelatinize the starch. Procedures for soaking and cooking are carefully controlled to produce suitable product properties and yields. After cooking, the water is drained and the parboiled rice is dried before milling in the same manner employed for ordinary rice milling.

Table 5

Parboiled Rice Milling Companies

Blue Ribbon Rice Mills, Inc.
Box 2587
Huston, Texas 77001

Comet Rice Mills, Inc.
Box 1681
Houston, Texas 77001

P&S Rice Mills, Inc.
Box 55040
Houston, Texas 77055

Rice Growers Association of
California 111 Sutter Street
San Francisco, California 94104
Plant: Sacramento, California

Riceland Foods
Box 927
Stuttgart, Arkansas 72160

Uncle Ben's, Inc.
Box 1752
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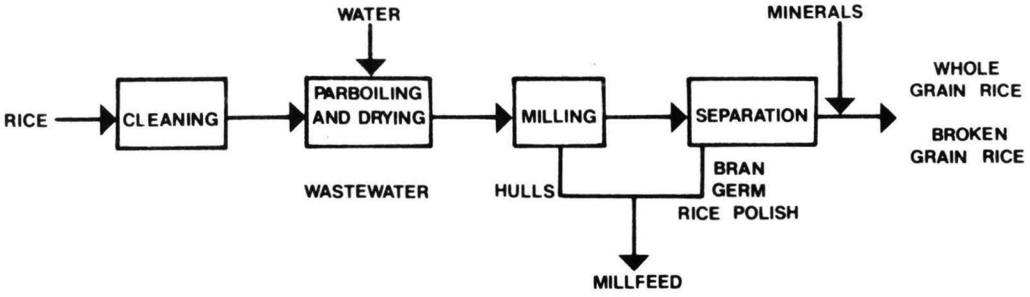

PARBOILED RICE MILLING

PRODUCTION PROCESSES

The production methods used in milling the various grains differ significantly in most cases as summarized earlier in this section. The following discussion provides a more detailed description for each industry subcategory of the processes used in milling.

Corn Wet Milling

Storage and Cleaning

Corn wet milling, shown in Figure 1, begins with the delivery to the plant of shelled corn, normally No. 3 grade or better. The corn is dry cleaned to remove foreign materials, stored, and dry cleaned a second time prior to entering the main production sequence.

Steeping

Steeping, the first step in the process, conditions the grain for subsequent milling and recovery of corn constituents. This process softens the kernel for milling, helps break down the protein holding the starch particles, and removes certain soluble constituents.

The steeping process consists of a series of tanks, usually referred to as steeps, and might be termed a batch-continuous operation. Each steep holds about 51 to 152 kkg (2000 to 6000 SBu) of corn, which is submerged in continuously recirculating hot water (about 50 degrees C). Sulfur dioxide in the form of sulfurous acid is added to the incoming water to aid in the steeping process.

As a fully-steeped tank of corn is discharged for further processing, fresh corn is added to that steep tank. Incoming water to the total steeping system is derived from recycled waters from other operations at the mill, and is first introduced into the tank with the oldest corn (in terms of steep time) and passes through the series of steeps to the newest batch of corn. Total steeping time ranges from 28 to 48 hours.

Steepwater Evaporation

Water drained from the newest corn steep is discharged to evaporators as so-called light steepwater containing about six percent of the original dry weight of the grain. On a dry weight basis, the solids in the steepwater contain 35 to 45 percent protein and are recovered for addition to feeds. Such recovery is effected by concentrating the steepwater to 30 to 55 percent solids in triple effect evaporators. The resulting steeping liquor, or heavy steepwater, is usually added to the fibrous milling residue which is sold as animal feed. Some steepwater

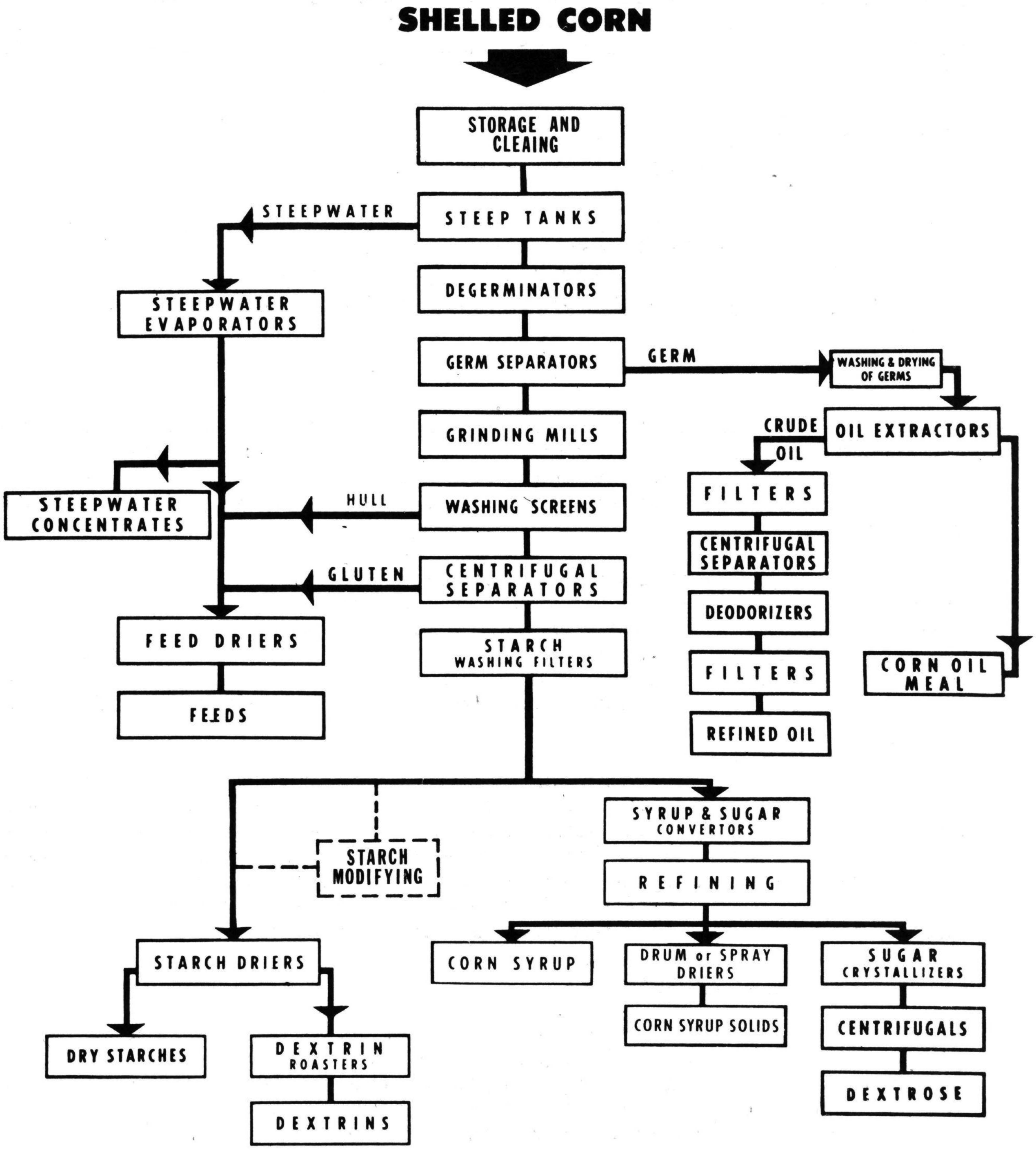

FIGURE 1
THE CORN WET MILLING PROCESS

may, also, be sold for use as a nutrient in fermentation processes.

Milling

The steeped corn then passes through degerminating mills which tear the kernel apart to free the germ and about half of the starch and gluten. The resultant pulpy material is pumped through liquid cyclones or flotation separators to extract the germ from the mixture of pulp, starch and gluten. The germ is subsequently washed, dewatered, dried, the oil extracted, and the spent germ then sold as corn oil meal.

The product slurry passes through a series of washing, grinding, and screening operations to separate the starch and gluten from the fibrous material. The hulls are discharged to the feed house where they are dried and used in animal feeds.

At this point, the main product stream contains starch, gluten, and soluble organic materials. The lower density gluten is then separated from the starch by centrifugation, generally, in two stages. A high quality gluten of 60 to 70 percent protein and 1.0 to 1.5 percent solids, is then centrifuged, dewatered, dried, and added to the animal feed. The centrifuge underflow containing the starch passes to starch washing filters to remove any residual gluten and solubles.

Starch Production

The pure starch slurry can now be directed into one of three basic finishing operations, namely ordinary dry starch, modified starches, and corn syrup and sugar. In the production of ordinary pearl starch, the starch slurry is dewatered using vacuum filters or basket centrifuges. The discharged starch cake has a moisture content of 35 to 42 percent and is further thermally dewatered by one of several different types of dryers. The dry starch is then packaged or shipped in bulk, or a portion may be used to make dextrin.

Modified starches are manufactured for various food and trade industries for special uses for which unmodified starches are not suitable. For example, large quantities of modified starches go into the manufacture of paper products, serving as binding for the fiber. Modifying is accomplished by treating the starch slurry with selected chemicals such as hydrochloric acid to produce acid-modified, sodium hypoclorite to produce oxidized, and ethylene oxide to produce hydroxyethyl starches. The treated starch is then washed, dried, and packaged for distribution. Since most chemical treatments result in a more water soluble product, waste waters from the washing of modified starches may contain a large concentration of BOD5. In addition, because of the presence of residual chemicals, and dissolved organic materials, these waste waters often cannot be reused and must be discharged to the sewer.

Syrup and Sugar-

In most corn wet mills, about 40 to 70 percent of the starch slurry is diverted to the corn syrup and sugar finishing department. Syrups and sugars are formed by hydrolyzing the starch, partial hydrolysis resulting in corn syrup and complete hydrolysis producing corn sugar. The hydrolysis step can be accomplished using mineral acids or enzymes, or a combination of both. The hydrolyzed product is then refined, a process which consists of decolorization with activated carbon and removal of inorganic salt impurities with ion exchange resins. The refined syrup is concentrated to the desired level in evaporators and cooled for storage and shipping.

The production of dextrose is quite similar to that of corn syrup, the major difference being that the hydrolysis process is allowed to go to completion. The hydrolyzed liquor is refined with activated carbon and ion exchange resins to remove color and inorganic salts, and the product stream is concentrated to the 70 to 75 percent solids range by evaporation. After cooling, the liquor is transferred to crystallizing vessels where it is seeded with sugar crystals from a previous batch. The solution is held for several days while the contents are further cooled and the dextrose crystallizes. After about 60 percent of the dextrose solids have crystallized, they are removed from the liquid by centrifuges, dried, and packed for shipment. A smaller portion of the syrup refinery is devoted to the production of corn syrup solids. In this operation, refined corn syrup is drum or spray-dried to generate corn syrup solids, which are somewhat more convenient to use than the liquid syrup.

Corn Dry Milling

The corn dry milling process is shown in Figure 2 and begins with Grade No. 2 or better shelled corn as the raw material. After dry cleaning, some mills wash the corn to remove any remaining mold. Waste waters from the washing operation normally go to mechanical solids recovery, using dewatering screens or settling tanks. The solids from this operation are added to the hominy feed and the spent wash water is discharged from the plant.

Tempering, the first process operation, raises the moisture content of the corn to the 21 to 25 percent level necessary for milling. The corn passes through a degerminator that releases the hull and germ from the endosperm and the product stream is dried and cooled in preparation for fractionation.

Fractionation comprises a series of roller mills, sifters, aspirators, and separators. The product stream first passes through corrugated roller mills or break rolls and then to sifters. This process may be repeated several times and, after the separation of the germ and hulls, the fine product stream goes to reduction mills to produce corn flour. Corn grits and meal are removed earlier in the fractionating sequence. The

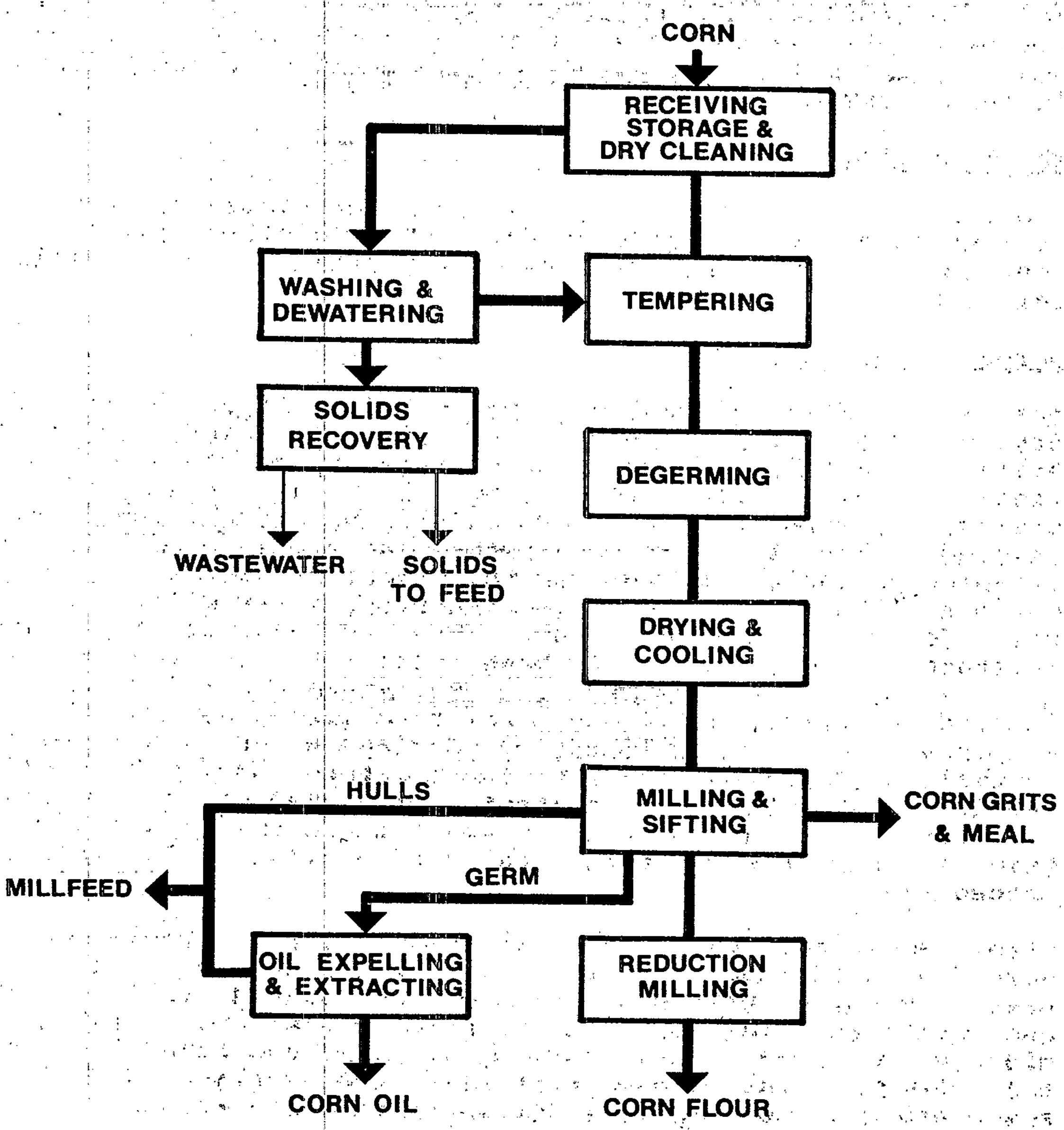

FIGURE 2
THE DRY CORN MILLING PROCESS

separated germ goes to oil expelling operations, where approximately 10.7 to 14.3 kg/kkg (0.6 to 0.8 lbs/SBu) of oil are recovered from the corn.

A few of the larger mills further process the grits, meal, and flour through expanders and/or extruders to produce food, foundry and feed products. Such processing is not an integral part of the basic milling sequence and is not practiced by most small and medium sized mills. Only the basic milling sequence is discussed in this document.

Wheat Milling

Wheat milling has been subdivided into two segments, normal flour milling and bulgur production. The production methods differ considerably and are discussed separately in the following paragraphs.

Normal Flour Milling-

The wheat milling process, presented in Figure 3, starts with dry, matured, graded, sound, and partly cleaned wheat seed. Grain, as needed, is moved from storage to the cleaning house for final cleaning prior to milling. It is here that other seeds, grains, and foreign matter such as sticks, stones, and dust are removed. The type of equipment and sequence of steps in the cleaning operation, as well as the extent of cleaning, may vary between mills. As a final cleaning step, a few mills use a water wash following air cleaning. The wash adds about one percent moisture to the original wheat and is believed to reduce microbiological contaminants. The excess water from washing is removed by centrifugal force. Prior to grinding, the wheat is tempered and conditioned by adding water under carefully controlled conditions to bring the moisture content up to desired levels, usually 15 to 20 percent. The amount and method of moisture addition, soaking time, temperature, and conditioning time will vary for different grades of grains and individual mill procedures.

After tempering, the wheat is ready for milling, which is normally performed in two sets of operations. The first, or break system, comprises a series of corrugated rolls, sifters, and purifiers. This milling operation breaks open the bran. The mixture of free bran, endosperm, germ, and bran with adhering endosperm are scalped over sifters. The scalped fractions of endosperm go into purifiers for separation and grading.

The second, or reduction, system consists of a series of smooth roller mills to reduce the granular middlings (endosperm) from the first system to flour. After each reduction, the product is sifted to separate the finished flour, germ, and the unground endosperm. The latter is sent back to reduction rolls for further processing. At the end of the milling operation, the discharged flour is treated with a bleaching agent to mature the

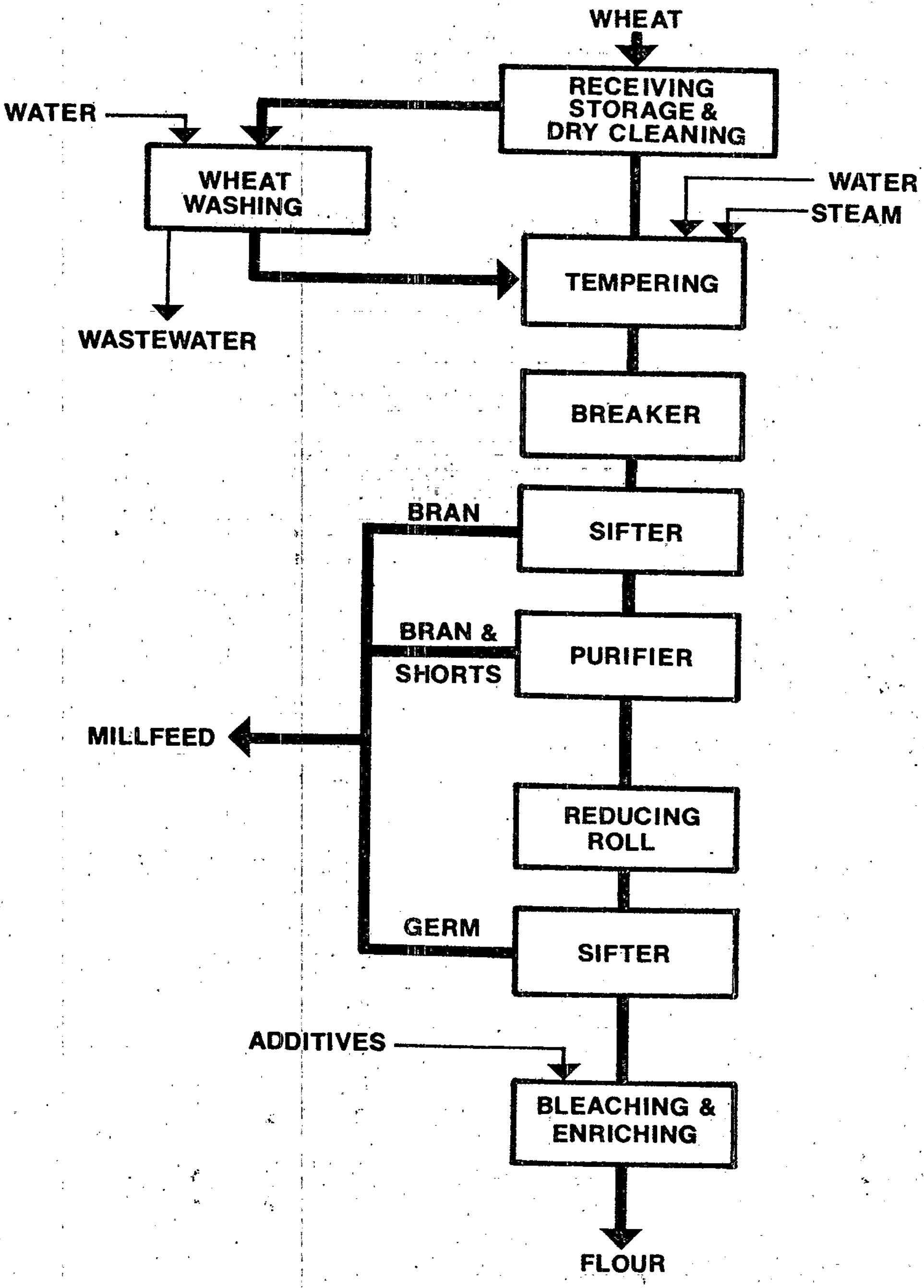

FIGURE 3

THE WHEAT MILLING PROCESS

flour and neutralize the color. Depending upon its end use, the flour may be blended or enriched. It is then directed into storage hoppers prior to packaging or bulk shipping.

Millers may vary the milling procedures used in the different steps described above. Flour emerges at several points in the process and may be kept separate or the various streams combined. The products from the individual mills differ in type and quantity of flour produced. By-products from the milling industry consist primarily of the wheat germ, shorts, bran, and unrecovered flour. These byproducts, know as millfeed, are generally used as animal and poultry feed additives.

Bulgur Milling-

Of the various processes in the manufacture of bulgur, the most familiar is a continuous mechanized system which is herein described and shown in Figure 4. As a first step, the wheat is thoroughly cleaned and graded by conventional cleaning processes to remove loose dust, dirt, and chaff. The wheat enters a washer which also raises the moisture content. From the washer, the wheat is conveyed to the top of the first of a series of soaking or tempering bins where the grain is conditioned as it progresses continuously through each bin from top entry to bottom of discharge. Water and live steam are added to the grain between each bin as it travels along a transfer conveyor from the bottom of the first bin to the top of the second. The process is repeated for the next bin with a progressively higher moisture content and temperature. Time, percent moisture, and temperature are all important variables and require close control during this soaking sequence.

Upon leaving the bottom of the last tempering bin, the wheat enters a pressurized steam cooker where the starch in the kernel is gelatinized. The cooked wheat is discharged to a series of two continuous dryers, the first for the removal of surface moisture and the second to reduce the moisture content to 10 to 11 percent.

Variations to the general procedures outlined above occur between manufacturing plants. Conventional grain milling procedures, similar to those used in normal flour production, follow the drying operations. The dried wheat is conveyed to a polisher (pearler or huller) followed by a series of grinders and sifters, which separate the fines and bran from the granular finished product. The combined by-products, approximately 10 percent of the raw materials, are disposed of as animal feed while the bulgur is packed in 100 lb bags for shipment.

Rice Milling

The raw material for rice milling may be one of several varieties of rice, which are normally classified as long grain (such as Bluebelle and Bluebonnet), medium grain (such as Nato and Nava),

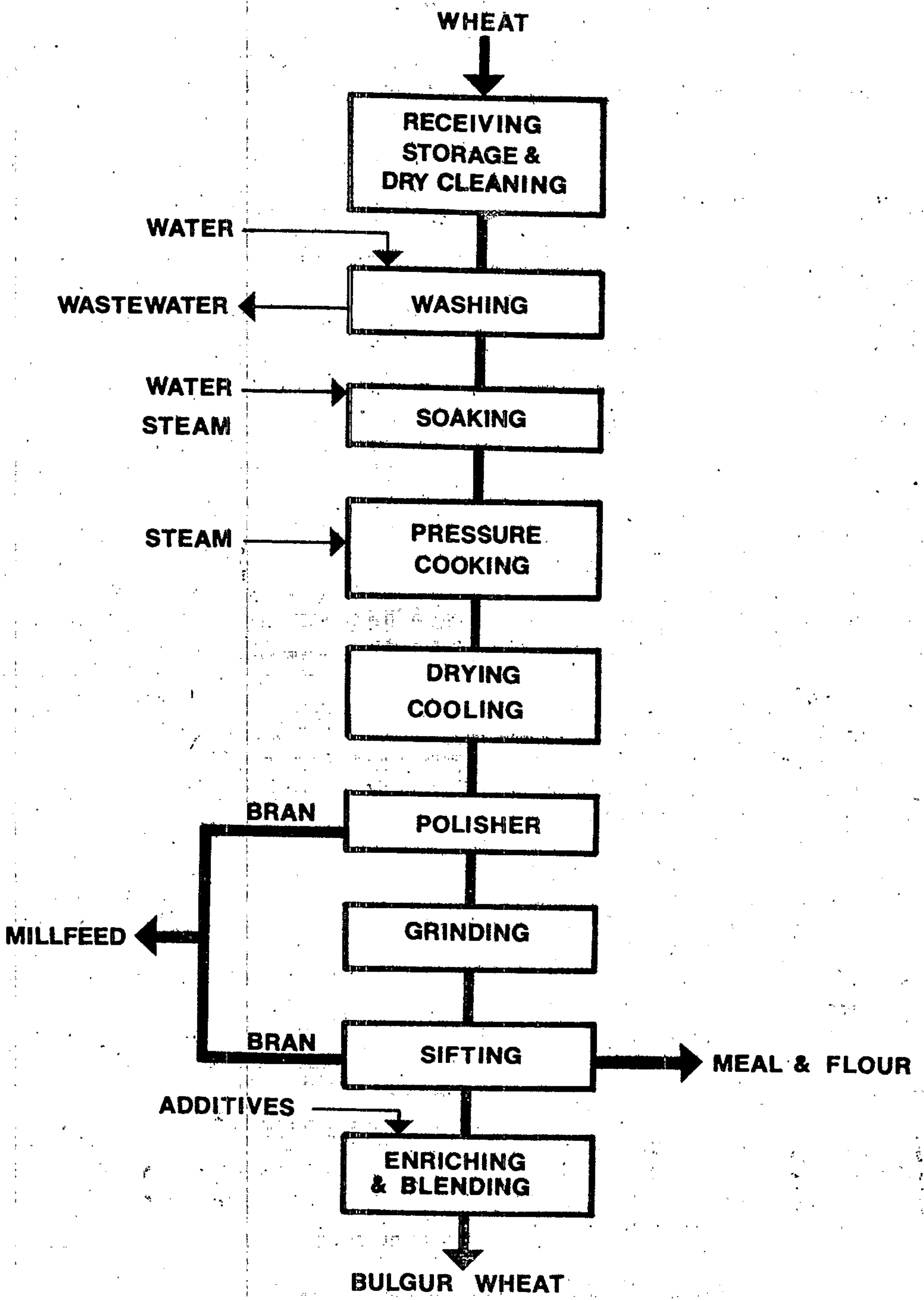

FIGURE 4

THE BULGUR PROCESS

and short grain (such as Pearl). Each variety is graded according to U.S. Department of Agriculture standards. In this country, the long grain rice is preferred.

Normal rice milling is a dry process operation and is described herein only to contrast it with parboiled rice production. The latter adds a cooking or parboiling step ahead of the conventional milling sequence.

Normal Rice Milling-

The production operations, shown in Figure 5, begin with the cleaning of the rough rice. Shaker screens and aspirators are used to remove foreign materials, hulls, and chaff. The cleaned rice is then dehulled in roller shellers or hullers with the loosened hulls removed by aspirators. Rough rice that is not dehulled is separated from the brown rice in a paddy machine, or separator, and returned to a second set of shellers.

At this point, brown rice may be removed as a finished product or processed through the complete milling operation. Calcium carbonate is added as an abrasive to help in removing the bran from the rice in the pearlers. In some cases, water is added to the brown rice to aid in the removal of tightly adhering bran layers and improve the adhesion of the calcium salt to the kernel. The pearlers remove most of the bran with some kernel breakage occuring. Some plants use pearlers in parallel as a one-break operation while some have twoand three-break systems to reduce breakage. Air through the pearlers removes the loose bran to a central bran bin and also cools the rice to reduce stress cracks. Additional processing in a brush machine removes the remaining loose bran.

Rotating horizontal drum trumbles are used to polish the rice. The rice is coated in the trumbles with talc and water, or glucose water, to fix the remaining bran to the kernels, which are then dried with warm air to produce the desired luster. Rice enriching is accomplished by adding vitamins and minerals, along with water, ahead of the trumbles. Finally, the whole and broken rice kernels are separated to meet product standards.

Parboiled Rice-

Parboiled rice production begins with basic rice cleaning in shakers and aspirators. Precision graders are added in parboiled rice cleaning to remove the immature small grains and the rice that has been dehulled in handling.

The parboiling process, as presented in Figure 6, may involve several variations, only one of which is discussed in this report. A measured amount of cleaned rough rice is dumped into the steeping tanks, which are then sealed. A vacuum is applied to remove most of the air in the hulls and the voids to allow water to penetrate into the kernel faster. Hot water (70 to 95

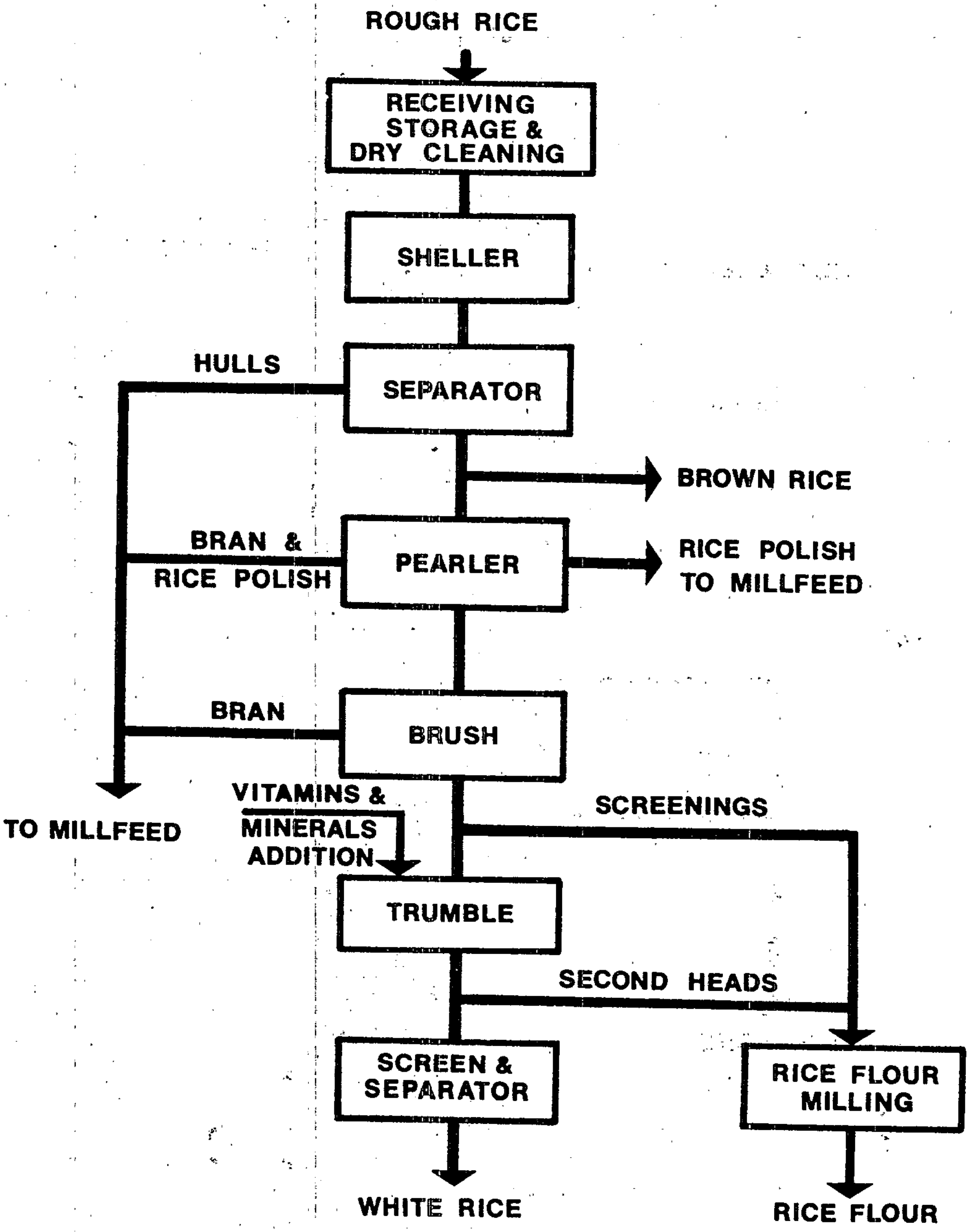

FIGURE 5

THE RICE MILLING PROCESS

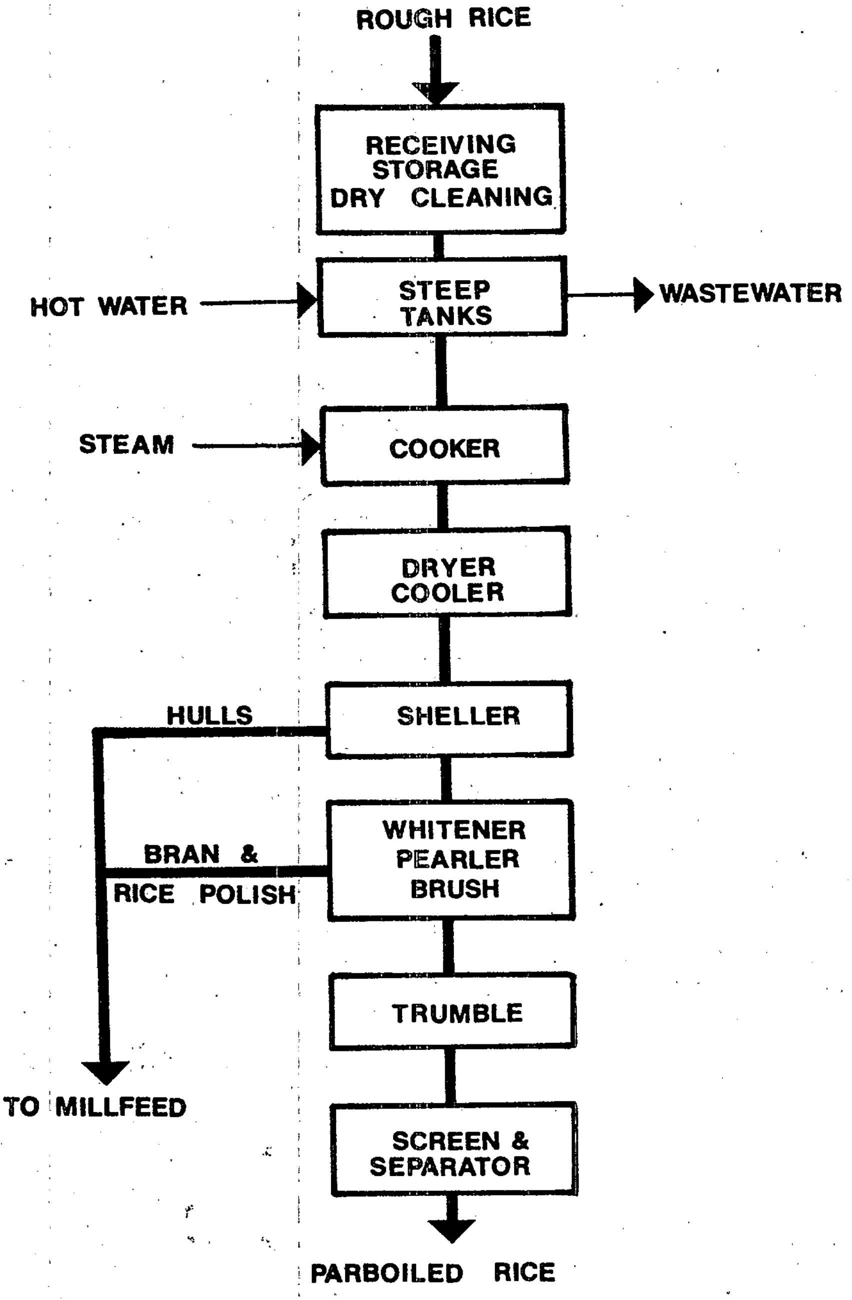

FIGURE 6

THE PARBOILED RICE PROCESS

degrees C) containing sodium bisulfite as a bleaching agent is added to cover the rice and the tank is pressurized to about 7.8 atm. The water is heated and recirculated to maintain close temperature control. When the grain moisture content reaches about 32 percent, the tank is drained and the rice is discharged into a cooker heated with live steam to gelatinize the starch. The parboiled rice is then dried and cooled before milling.

Besides steeping water discharge, waste waters may be generated from barometric condensers on the dryer vacuum system and from wet scrubbers on the other dryers. Steepwater is not reusable for steeping because of the color pick-up, which would discolor the rice.

In parboiled rice milling, machines called whiteners are used in series with pearlers to loosen the bran. Otherwise, the milling process is essentially the same as for normal rice.

WASTE WATER CONSIDERATIONS IN INDUSTRY

Of the four subcategories of grain milling covered in this report, only corn wet milling generated large quantities of waste waters. Water use in the corn wet mills ranges from about 3785 to 189,000 cu m/day (1 to 50 mgd). Large quantities of BOD_5 and suspended solids are discharged in the waste water, and hence, waste waters from these mills potentially constitute major sources of pollution. At the present time, only six corn wet mills discharge directly to receiving waters. Three of these provide biological treatment, one is constructing a treatment plant, and the fifth will be discharging to a new numicipal system now under construction. The sixth discharges only once-through barometric condenser water. The remainder discharge untreated or, in at least four cases, pretreated waste waters to existing municipal treatment facilities.

There are two potential sources of waste waters from corn dry mills, namely corn washing and car washing. Corn washing has been a standard operation at many, but not all, mills while car washing is practiced infrequently and only at some mills. The quantities of waste waters are relatively small, compared to corn wet mills, ranging up to perhaps 900 cu m/day (240,000 gpd), but the wastes typically have high suspended solids and BOD_5 concentrations. Most corn dry mills now discharge their waste waters to municipal systems.

Ordinary wheat milling usually generates no process waste waters. A few mills wash the wheat and some infrequently wash cars. Bulgur mills produce a small quantity of waste water, 38 to 113 cu m/day (10,000 to 30,000 gpd) from the soaking and cooking operation. These waste waters contain moderately high levels of BOD_5 and suspended solids. All of the five bulgur mills in the country are believed to discharge these wastes to municipal systems for treatment. Normal rice milling does not use any process waters, hence no process waste waters. Parboiled rice does generate some waste waters from the parboiling or steeping operation, up to about 760 cu m/day (200,000 gpd). These waste waters are high in dissolved BOD, but low in suspended solids. At least five of the six rice parboiling plants discharge these wastes to municipal system.

SECTION IV

INDUSTRY CATEGORIZATION

The Phase I study of the grain milling industry covers the primary milling of the three principal cereal grains, namely, corn, wheat, and rice. After considering various factors, it was concluded that the industry should be categorized into several discrete segments for purposes of developing effluent limitations. These subcategories are as follows:

1. Corn wet milling
2. Corn dry milling
3. Normal wheat flour milling
4. Bulgur wheat flour milling
5. Normal rice milling
6. Parboiled rice milling

FACTORS CONSIDERED

The factors considered in developing the above categories included:

1. Raw materials
2. Finished products
3. Production processes or methods
4. Size and age of production facilities
5. Waste water characteristics
6. Treatability of wastes

Careful examination of all available information indicated that two of these factors, specifically raw materials and production processes, provided a meaningful basis for categorization, as summarized in the ensuing paragraphs.

Raw Materials

Clearly, one basis for segmenting the industry would be the three different raw agricultural products used, specifically corn, wheat, and rice. The three grains have very distinct physical and chemical characteristics. As described below, they also produce distinct raw waste water characteristics. Accordingly, raw materials were selected as one basis for subcategorization.

Finished Products

The finished products from the milling of the different grains are quite distinct. Corn milling products range from corn meal and grits to starch and syrup. Wheat milling produces flour for baking and other purposes and the specialty product, bulgur. Finally, rice milling yields ordinary and parboiled rice for direct human consumption. The wide variety of finished products, however, especially from corn milling, make further segmentation based on finished products impractical. In a broad sense, the categorization does reflect the finished products inasmuch as each subcategory generates different product lines. The finished products, however, are not themselves basis for subcategorization.

Production Processes

While similar in some respects, the production methods used in milling form an excellent basis for subcategorizing the industry. The most marked differences in production processes are the techniques used in corn wet milling. These highly sophisticated physical, chemical, and biological processes are completely different from most process operations in dry corn, wheat, and rice mills.

Dry corn and ordinary wheat milling employ somewhat similar processes. Both require cleaning, tempering, milling, and mechanical separation of the products although slightly different equipment is used. Bulgur wheat milling differs considerably from ordinary flour milling in production method, thereby providing a basis for further subdividing wheat milling.

Rice milling involves distinctly different techniques and equipment than other grain milling operations. Moreover, parboiled rice requires several additional production steps, thereby justifying further subdivision of rice milling into normal rice milling and parboiled rice production.

Size and Age of Production Facilities

There appears to be little rationale for subcategorization based on size or age of milling facilities. Certainly there is no correlation between large and small mills considering the entire industry as one group. For example, a large corn wet mill has nothing in common with a large rice, wheat, or dry corn mill. Similarly, no relationship can be established for age of plant for the industry as a whole.

Within any of the subcategories defined previously, it must be acknowledged that relationships may exist between size or age of production facilities. However, with the information developed in this study no correlations could be established between waste characteristics and size or age of plants.

Waste Water Characteristics

The waste water characteristics from the several types of grain mills do differ to some degree. Wet corn mills typically generate large volumes of wastes containing large total amounts of BOD5 and suspended solids, the concentrations of which depend on the quantities of once-through contact cooling waters.

Corn dry mills discharge much smaller waste water quantities with high BOD5 and suspended solids levels. Parboiled rice mills generate amounts of waste water that are comparable to corn dry mills and with a high dissolved BOD5 content. Suspended solids levels, however, are quite low in rice milling wastes. Finally, bulgur milling generates small quantities of moderately strong wastes.

In summary, while the waste water characteristics do differ, sometimes significantly, these differences are adequately reflected by the other factors mentioned above.

Treatability of Wastes

All of the waste waters from the grain milling operations covered by this document are amenable to physical and biological treatment systems of the same general type. In general, the fundamental design criteria will be similar and treatability is not a satisfactory means for subcategorization.

SECTION V

WATER USE AND WASTE WATER CHARACTERIZATION

INTRODUCTION

Process water use and waste water discharges vary markedly in the industry subcategories covered by this document, ranging from extremely high uses and discharges in the corn wet milling segment to virtually no process waste waters in ordinary flour and rice milling. By far the largest water users and hence, the greatest waste water dischargers are the corn wet mills. The very nature of corn wet milling processes is different from other segments of the grain milling industry. In effect, these plants are large chemical complexes involving, as their name implies, wet production methods.

Dry corn and normal wheat milling may employ water to clean the incoming grain, although many plants, particularly the wheat mills, use mechanical methods for grain cleaning. Bulgur and parboiled rice manufacturing techniques require water for steeping or cooking and hence, generate modest quantities of process waste waters.

This section presents a detailed discussion of water use, individual process and total plant waste water characteristics, and factors that might influence the nature of the waste waters generated. The information presented has been collected from state and federal regulatory surveys, Corps of Engineers permit applications, industrial sources, literature, and the results of a series of sampling visits to selected plants in each industrial subcategory. The source of data is described in more detail in Section III. Moreover, the sampling program provided limited information on the waste water characteristics from individual plant processes, particularly in the corn wet milling subcategory.

In general, information on waste characteristics from cooling water and boiler blowdown and water treatment plant wastes has been excluded from the following discussion. These auxiliary activities are common to many industries and the individual practices at any given plant usually do not reflect conditions that are unique to the grain milling industry. The types of treatment employed for cooling water systems, boiler feed water, and process water vary widely throughout the industry and depend on such factors as raw water characteristics, availability of surface or city water, individual company preferences, and other considerations not related to the basic nature of the industry. Separate guidelines for auxiliary wastes common to many industries will be proposed by EPA at a later date.

CORN WET MILLING

Water Use

For clarity in presentation, the basic corn wet milling operations have been divided into three process water and waste water flow diagrams, Figures 7, 8, and 9. These diagrams cover the basic milling operation, starch production, and syrup refining, respectively.

The modern wet corn mill, in many respects, is already a "bottled up" plant, compared to its ancestors of 50 to 75 years ago. Historically, this segment of the industry has succeeded in reducing the fresh water consumption per unit of raw material used in the basic production operations exclusive of cooling waters. The waste waters from one source are now used as makeup water for other production operations. Fresh water, recycled process waste waters, and discharged waste waters are shown on the attached diagrams. Recycled process waste waters are identified by the symbol "PW" to distinguish them from waste waters that are sewered.

Fresh water enters the overall corn wet milling production sequence primarily in the starch washing operations. This water then moves countercurrent to the product flow direction back through the mill house to the steepwater evaporators. More specifically, the process waste waters from starch washing are reused several times in primary starch separation, fiber washing, germ washing, milling, and finally as the input water to the corn steeping operation. The principal sources of waste waters discharged to the sewer from this sequence of operations are modified starch washing, and condensate from steepwater evaporation.

Additional fresh water is used in the syrup refinery. Although practice varies within the industry, fresh water may be introduced in starch treating, neutralizing, enzyme production, carbon treatment, ion exchange, dextrose production, and syrup shipping, as indicated in Figure 9. In some plants, evaporator condensate is used to supply many of these fresh water requirements, particularly in carbon treatment and ion exchange regeneration. Other process waste waters are used in mud separation, syrup evaporation, animal feeds, and corn steeping.

Total water use in this subcategory varies from less than 3785 cu m/day up to 190,000 cu m/day (1.0 mgd to 50 mgd) depending, in large measure, on the types of cooling systems employed. Those plants using once-through cooling water have much higher water demands than those using recirculated systems, whether they be surface or barometric condensers. The water use per unit of raw material ranges from about 0.0067 to 0.0745 cu m/kkg of corn grind (45 to 500 gal/MSBu). Those plants that predominantly use once-through cooling water will have total water use values of about 0.045 cu m/kkg of grind (300 gal/MSBu). This number should be contrasted with the several plants that use recirculated cooling water almost exclusively, where the total water use

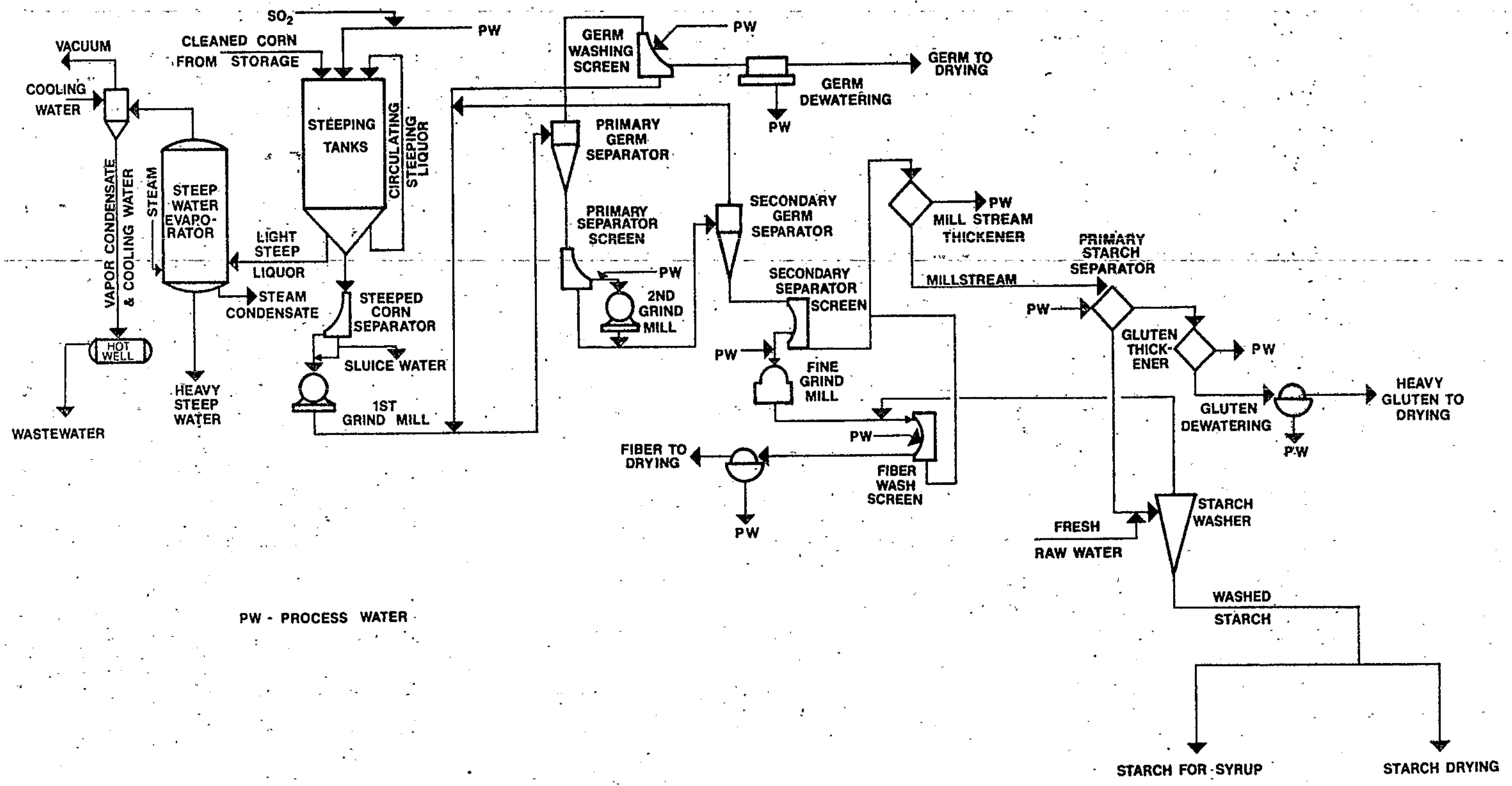

FIGURE 7

BASIC MILLING OPERATIONS IN A TYPICAL CORN WET MILL

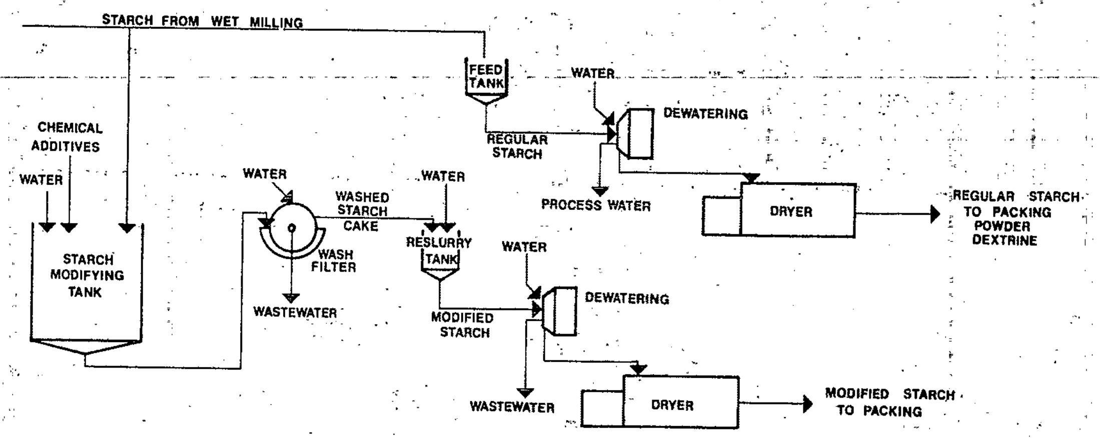

FIGURE 8

FINISHED STARCH PRODUCTION IN A TYPICAL CORN WET MILL

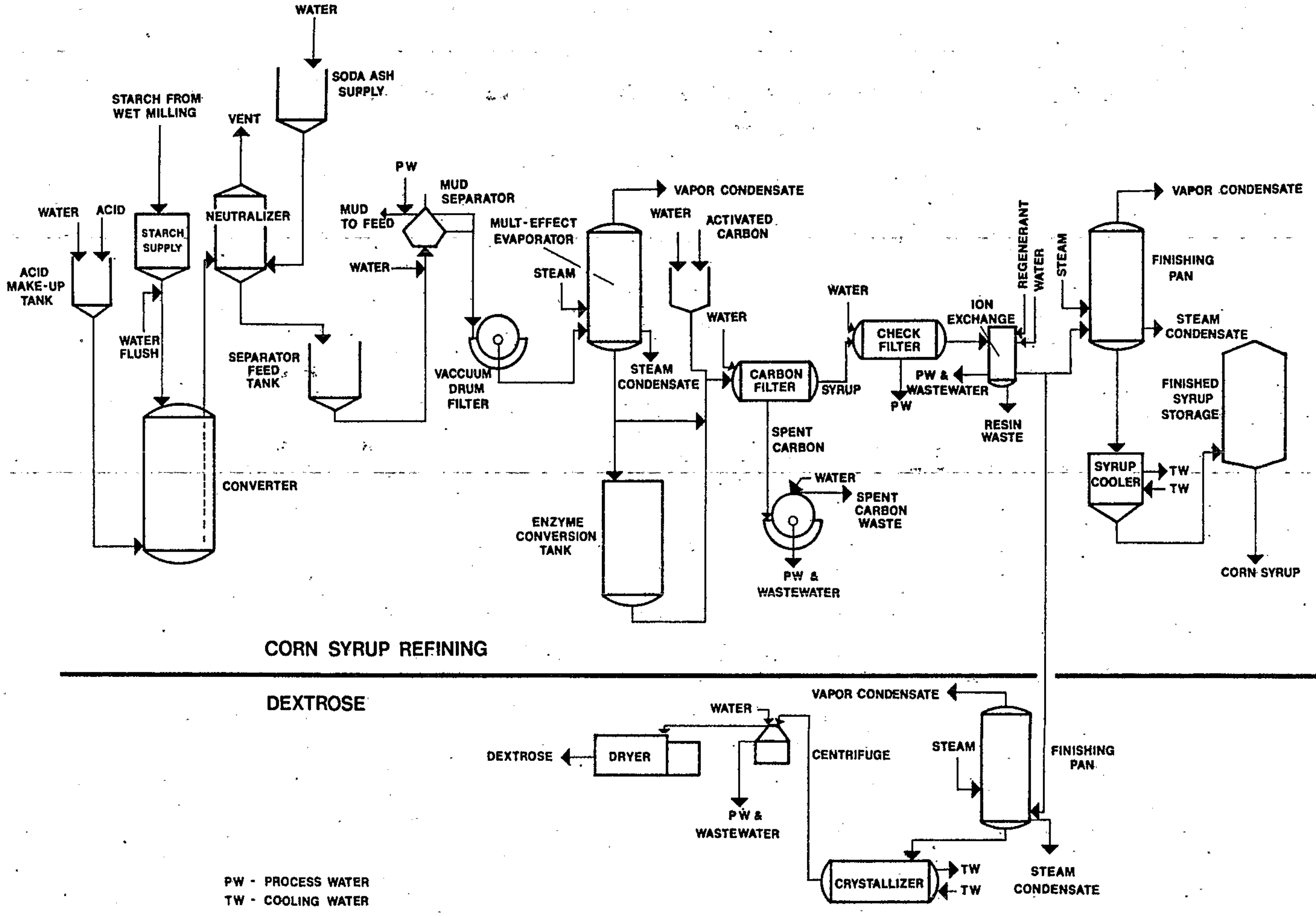

FIGURE 9

SYRUP PRODUCTION IN A TYPICAL CORN WET MILL values are about 0.0075 cu m/kkg (50 gal/MSBu). Information is not available on the water use by individual production processes since these vary from plant to plant. Company preferences, type of equipment, product mix, and other factors all influence the water use in terms of both the individual processes and the total plant.

Waste Water Characteristics of Individual Production Processes

As indicated in the preceding discussion on water use, many process waste waters that were discharged to sewers years ago, are now recycled back into the process. This section is concerned only with those wastes that are generally discharged to the sewer as shown previously in Figures 7, 8 and 9. Major wastes included are those from steepwater evaporators; starch modifying washing, and dewatering; syrup refining (cooling, activated carbon treatment, and ion exchange regeneration); syrup evaporation; and syrup shipping.

Steepwater Evaporation-

The condensate from steepwater evaporation constitutes one of the several major waste water sources in a corn wet mill. Normally, triple-effect evaporators are used with either surface or barometric condensers. Vapors from each of the first two effects passes through the subsequent effect before being discharged to the sewer. For those systems using surface condensers, the condensate from the third effect is sewered. In the case of barometric condensers, the third effect condensate becomes a part of the barometric cooling water discharge and hence, is greatly diluted. Limited data on characteristics of the waste discharges from the first and second effect evaporators were acquired during the sampling program and are presented in Table 6. Selected samples taken from the barometric cooling waters serving the third effect evaporator, indicate much lower waste concentrations, as expected. BOD5 levels ranged from 10 to 75 mg/l with typical values reported by industry in the range of 25 mg/l.

Table 6
First and Second Effect Steepwater Condensate
Waste Water Characteristics

	Range, mg/l
BOD5	723 - 934
COD	1095 - 1410
Suspended Solids	10 - 28
Dissolved Solids	110 - 292
Phosphorus as P	0.5 - 0.7
Total Nitrogen as N	2.4 - 2.6
pH	3.0 - 3.5

Surface condensers will generate essentially the same total quantity of waste constituents, but in a much smaller volume of water. To reduce waste water flows, several plants presently recirculate barometric cooling water and only discharge the blowdown from the cooling tower to the sewers. Measurements of the blowdown from such a system at one plant indicated a BOD5 of about 440 mg/l and a suspended solids content of 80 mg/l.

Data from a previous study for the Environmental Protection Agency (Table 7) indicate that steepwater evaporation systems using oncethrough cooling water generate about 4.5 to 13.4 cu m/kkg (30 to 90 gal/SBu) of process wastes. Recirculating cooling water systems, on the other hand, generate about 10 percent of this flow, namely 0.6 to 0.9 cu m/kkg (4 to 6 gal/SBu).

Additional data from the same study related waste characteristics to raw material input and indicated a BOD5 range of 0.9 to 2.9 kg/kkg (0.05 to 0.16 lbs/SBu) and a COD range 1.1 to 3.2 kg/kkg (0.06 to 0.18 lbs/SBu).

Modified Starch Production

In many, if not most, corn wet mills the waste from the production of modified starches represents the largest single source of contaminants in terms of organic load. Limited samples taken at two mills indicated very high BOD, COD, and dissolved and suspended solids, as indicated in Table 7.

Table 7
Finished Starch Production
Waste Water Characteristics

	Range, mg/l
BOD5	3549 - 3590
COD	8250 - 8686
Suspended solids	918 - 2040
Dissolved solids	9233 - 16211
Phosphorus as P	25 - 63
Total nitrogen as N	32 - 41
pH	4.2- 5.7

These very high-strength wastes are highly variable in both composition, flow and biodegradability. Information from earlier studies on the waste characteristics relative to raw material input is summarized in Table 8.

It is important to note that the production of modified starches varies not only from plant to plant, but from day to day and week to week in any given plant. Moreover, the nature of the waste water generated from starch modification depends on the particular starches being manufactured. For example, mild oxidation with sodium hypochlorite generates a lower dissolved organic load than highly oxidized starch production. No correlation has yet been established between the types and amounts of starches being produced and the waste loads from this operation.

Syrup Refinery-

In most mills, waste waters are discharged from several operations in the syrup refinery. Most of these waste waters are generated by the series of operations generally referred to as syrup refining, which includes activated carbon and ion exchange treatment. Typically, the so-called sweetening-off procedures require flushing the spent carbon or ion exchange resin with water prior to regeneration. The first flush of such water is usually sent to the syrup evaporator for reclamation. The final rinse water is very dilute in syrup content and is discharged from the plant. Sampling data indicate that waste waters from the ion exchange regeneration are high in organic content, with BOD5 levels of 500 to 900 mg/l, and in dissolved solids, 2100 to 9400 mg/l. The pH levels of the waste water were quite low, averaging about 1.8 and the suspended solids averaged 25 mg/l.

Other sources of waste waters in the syrup refinery include: syrup (flash) cooling, evaporation, dextrose production, and shipping. Samples of wastes from the syrup cooling process at one plant gave the results shown in Table 9.

Table 8
Individual Process Waste Loads
Corn Wet Milling

Manufacturing Process	Flow		BOD		COD		Dissolved Solids		Total Solids	
	cu m/kkg	gals/SBu	kg/kkg	lbs/MSBu	kg/kkg	lbs/MSBu	kg/kkg	lbs/MSBu	kg/kkg	lbs/MSBu
Steepwater evaporation	0.6-13.4	4-90	0.9-2.9	50-160	1.1-3.2	60-180	3.4-3.9	190-220	4.3-4.6	240-260
Feed dewatering	0.3-0.6	2-4	0.2	10	-	-	0.2-0.5	10-30	-	-
Oil refining	0.03-3.7	0.2-25	0.04-0.5	2-30	-	-	0.2-0.4	10-20	0.2-0.5	10-30
Starch modifying, washing, etc.	1.5-7.5	10-50	1.8-10.7	100-600	2.3-10.7	130-600	13.0-28.6	730-1600	15.7-44.7	880-2500
Syrup refining (carbon, ion exchange)	3.7	25	2.7	150	9.3	520	10.4	580	10.5	590
Syrup evaporation	0.3-30	2-200	1.3	70	2.5	140	1.1-6.1	60-340	1.1-9.5	60-530
Corn syrup shipping	0.3-0.4	2-3	0.9	50	1.4	80	1.3	70	1.2	70
Dextrose and corn syrup solids	-	-	-	-	-	-	1.8-2.1	100-120	-	-

Table 9
Corn Syrup Cooling
Waste Water Characteristics

	Concentration
BOD5	73
COD	177
Suspended solids	44
Dissolved solids	291
Phosphorus as P	0.2
Total nitrogen as N	0.4
pH	6.7

The concentration of wastes from syrup evaporation again depends on the type of condensers used, i.e., surface and barometric with recirculation versus barometric with once-through cooling water. Other data on the waste waters from the various activities in a syrup refinery are included in Table 7.

Other Processes-

Waste water streams of less importance include discharges from feed dewatering, oil extraction and refining, and general plant cleanup. Sampling data taken at one plant indicate that the waste waters from the feed house contained about 140 mg/l of COD, 40 mg/l of suspended solids, and negligible amounts of phosphorus and nitrogen, and had a pH of 5.9. Other data are also presented in Table 7.

Total Waste Characteristics

Most of the data accumulated from various sources during this study relate to the total raw waste characteristics from corn wet mills. Summary data from 12 of the 17 mills are presented in Table 10. Waste waters from this grain milling subcategory can generally be characterized as high-volume, high-strength discharges. The BOD varies widely, from 255 to 4450 mg/l, with a corresponding range in COD. Those plants with very low BOD5 values typically have barometric condensing systems using once-through cooling water. At the other extreme, the very concentrated wastes are from plants using recirculated cooling water (either surface or barometric condensers).

Suspended solids levels in the total waste streams show similar variations ranging from 81 to 2458 mg/l. Once again, the plants with low suspended solids concentrations are those using barometric condensers with once-through cooling water.

Other waste parameters indicate that the pH of the total waste ranges from about 6.0 to 8.0. These average pH values, however, are somewhat misleading inasmuch as wide pH fluctuations are common to many plants. Typically, the waste may be somewhat

Table 10
Total Plant Raw Wastewater Characteristics
Corn Wet Milling

Plant	BOD, mg/l		COD, mg/l		Suspended Solids, mg/l		pH	
	Average	Range	Average	Range	Average	Range	Average	Range
1	1400	400-3000	-	-	1200	66-4628	5.9	4.7-9.4
2	1625	464-4320	2100	-	477	100-3490	6.5	1.4-10.4
3	614	-	-	-	700	-	-	-
4	2880	650-7800	-	-	1230	170-5200	6.1	4.1-9.5
5	450	-	-	-	-	-	-	4.5-8.2
6	444	303-526	798	-	288	225-335	-	-
7	2330	288-25,000	4560	347-40,000	895	43-18,000	7.1	5.0-11.3
8	4450	780-11,000	-	-	2458	410-9400	-	-
9	1650	1246-2370	3500	750-10,300	700	-	6.0	-
10	998	146-4618	-	-	259	8-3216	7.2	5.4-9.8
11	225	-	473	-	81	-	-	-
12	2584	67-9592	-	-	862	19-7744	7.9	1.8-12.0

deficient in nitrogen for biological waste treatment. Dissolved solids levels from certain process operations, as discussed previously, generally do not constitute a problem when combined in the total waste stream. In those plants that have minimized water use, dissolved solids build-up may be a future concern.

The information contained in the preceding table is presented in Table 11 in terms of raw material input, i.e., kg/kkg (lbs/MSBu). <u>The plant numbers in the two tables do not correspond to one another.</u>

BOD5 in terms of raw material input ranges from 2.1 to 12.5 kg/kkg (119 to 699 lbs/MSBu), and averages 7.4 kg/kkg (415 lbs/MSBu). Similarly, the suspended solids in the total plant waste waters range from 0.5 to 9.8 kg/kkg (29 to 548 lbs/MSBu) and average 3.8 kg/kkg (211 lbs/MSBu). These data emphasize again the wide variation in waste characteristics from the corn wet milling industry. Possible correlations between plant size, age, or other factors will be discussed in the next section. The waste water flows vary from 3.1 to 41.7 cu m/kkg (21 to 280 gal/SBu) with an average of 18.3 cu m/kkg (123 gal/SBu). Those plants with lower waste flows per unit of production are those that employ recirculating cooling water systems.

<u>Factors Affecting Waste Characteristics</u>

As noted previously, waste waters from corn wet milling plants vary greatly in quantity and character. This variability is a function of many different factors and attempts have been made in this study to correlate some of these factors with raw waste loads, as discussed in the following paragraphs.

<u>Age of Plant</u>-

In some industries, the character of waste generated is directly related to the age of the plants. Such is not the case in corn wet milling, as evidenced in Figure 10, which relates plant age to the BOD5 in the total plant effluent. The data have been gathered into three groupings with a dark circle representing the mean, and the boundaries of the rectangles representing the range of average values in each grouping. Clearly, there is no discernible relationship between the total waste load and the age of the plants. In fact, at least one of the new plants generates more wastes per unit of raw material input than several of the older plants. It should be noted that the age of plant in this industry does not accurately reflect the degree of modernization in terms of types of equipment. Because of competition and market demands, most corn wet mills are reasonably modern and very similar in basic production techniques.

<u>Size of Plant</u>-

Several comparisons were made between the size of plant, expressed in normal grind of raw material, and total plant waste

Table 11
Wastewater Characteristics per Unit of Raw Material
Corn Wet Milling

Plant	Flow		BOD		COD		Suspended Solids	
	cu m/kkg	gals/SBu	kg/kkg	lbs/MSBu	kg/kkg	lbs/MSBu	kg/kkg	lbs/MSBu
1	16.7	112	7.0	394	-	-	3.9	219
2	28.0	188	12.4	693	22.3	1248	8.0	450
3	41.7	280	8.9	499	16.4	920	2.8	159
4	6.4	43	12.5	699	19.6	1100	4.0	223
5	25.6	172	4.4	246	10.5	589	2.6	148
6	3.1	21	2.1	119	-	-	0.5	29
7	40.4	271	4.0	225	-	-	1.3	70
8	10.6	71	5.3	299	6.8	378	2.3	127
9	4.9	33	10.5	590	20.6	1153	4.0	226
10	6.7	45	4.1	230	7.0	394	4.7	262
11	27.9	187	6.3	350	-	-	1.2	68
12	8.2	55	11.4	639	-	-	9.8	548
Average	18.3	123	7.4	415	14.8	826	3.8	211

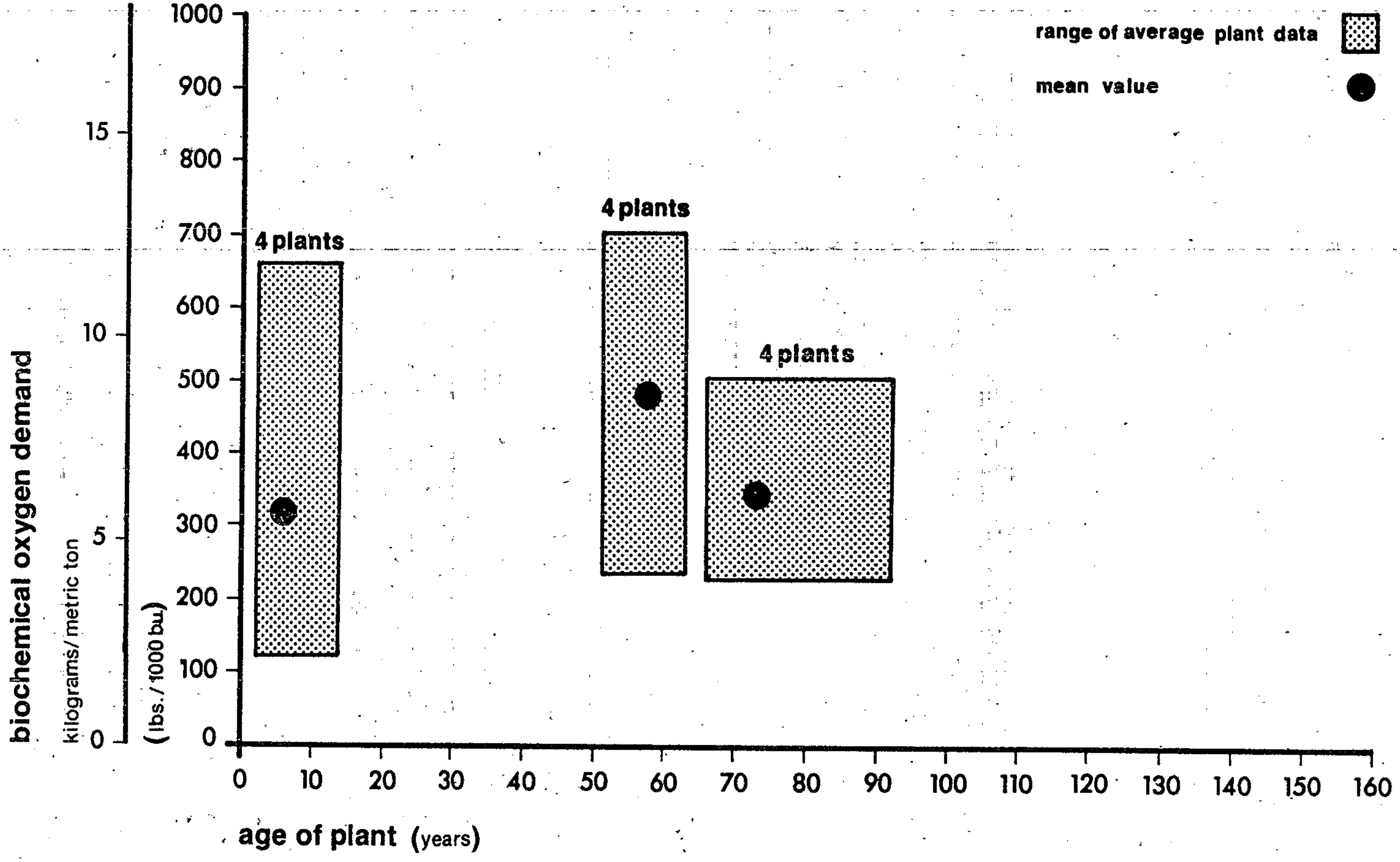

FIGURE 10
EFFECT OF WET CORN MILLING PLANT AGE ON AVERAGE BOD DISCHARGED

loads as shown in Figures 11, 12 and 13. The total daily volume of waste water discharged was found to show a general relationship with the plant capacity, Figure 11, as might be expected. At the same time, the data reflect a wide range in waste water discharges as a result of vastly different process and cooling water use practices.

The information on BOD5 and suspended solids has been grouped into three plant size ranges, which might be termed small, medium, and large. As shown in Figures 12 and 13, no discernible relationship can be found between plant capacity and either of these two pollutant parameters.

Water Use and Waste Water Discharge-

It has been speculated that there might be a relationship between the total waste load and the volume of water used or discharged.

Figures 14 and 15 were developed to evaluate this hypothesis and clearly indicate that no such correlation exists. Once again, the data have been grouped in a convenient manner for presentation.

Product Mix-

Because certain products, namely modified starches, result in higher waste loadings than other products, there was reason to believe that a relationship might be apparent between product mix and total waste load. For example, it might be reasoned that a plant producing only corn syrup would have a lower raw waste load per unit of raw material input than one producing a product mix with a high percentage of modified starches. The available data from 12 plants regarding both product mix and raw waste characteristics showed absolutely no correlation between these two variables. It is known that changes in product mix at a given plant will alter the total plant raw waste load, but the data refute any claim that product mix is a direct measure of the relative waste load of different plants.

The product mix at the reporting mills varied from 100 percent starch to 100 percent syrup and sugar. At most of the plants, the product mix varied between about 30 and 70 percent starch. Even near the two extremes, i.e., zero and 100 percent starch, there was no discernible relationship between product split and waste loads. Furthermore, the more limited information on the quantities of modified starches produced indicated no correlation with waste loads at different plants.

Plant Operating Procedures-

There appears to be a definite relationship between general plant operating procedures and the amounts of wastes discharged. Those plants known to have good housekeeping operations and close operational control do tend to have lower waste loads, although

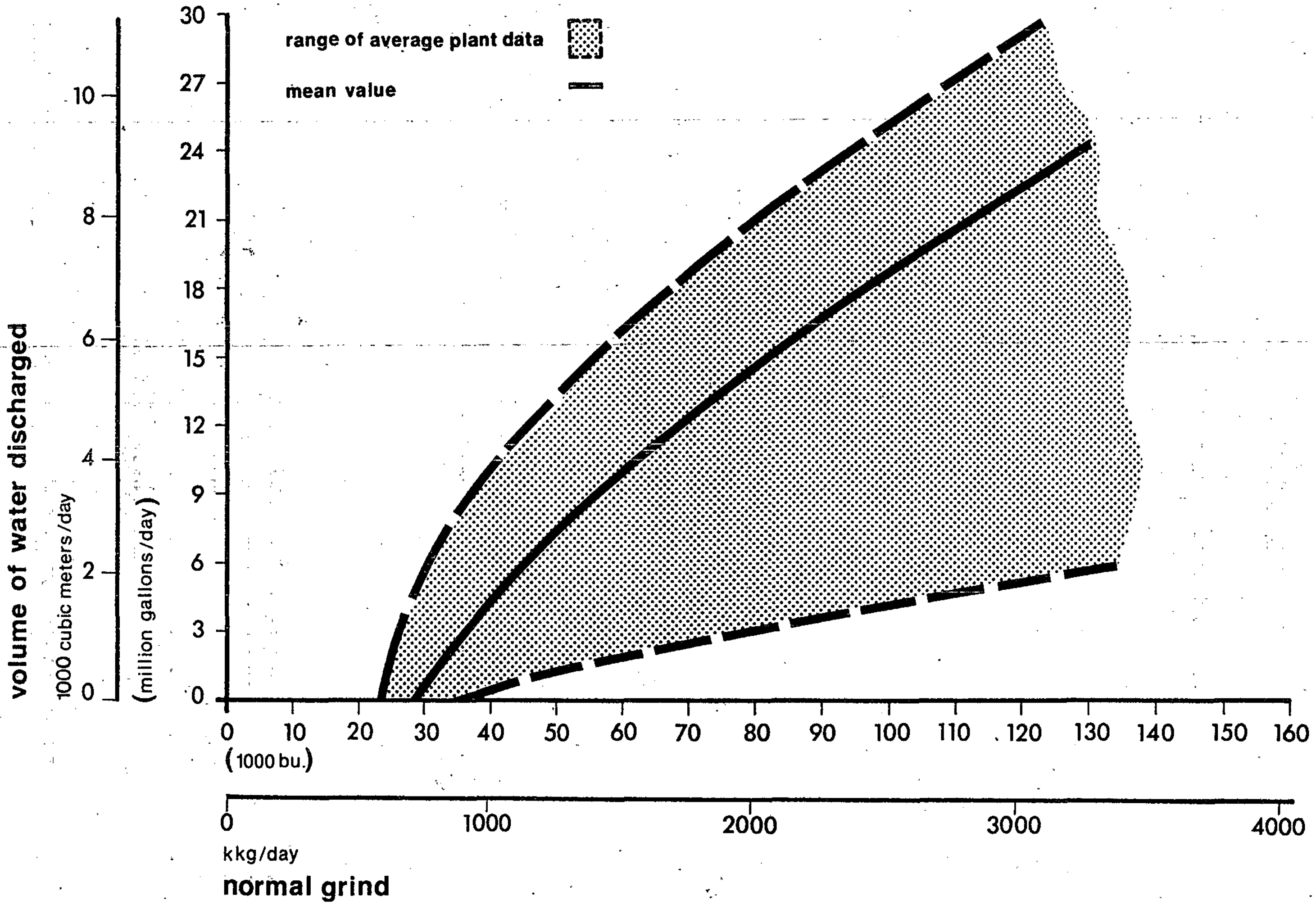

FIGURE 11
QUANTITY OF WASTEWATER DISCHARGED BY CORN WET MILLING PLANTS

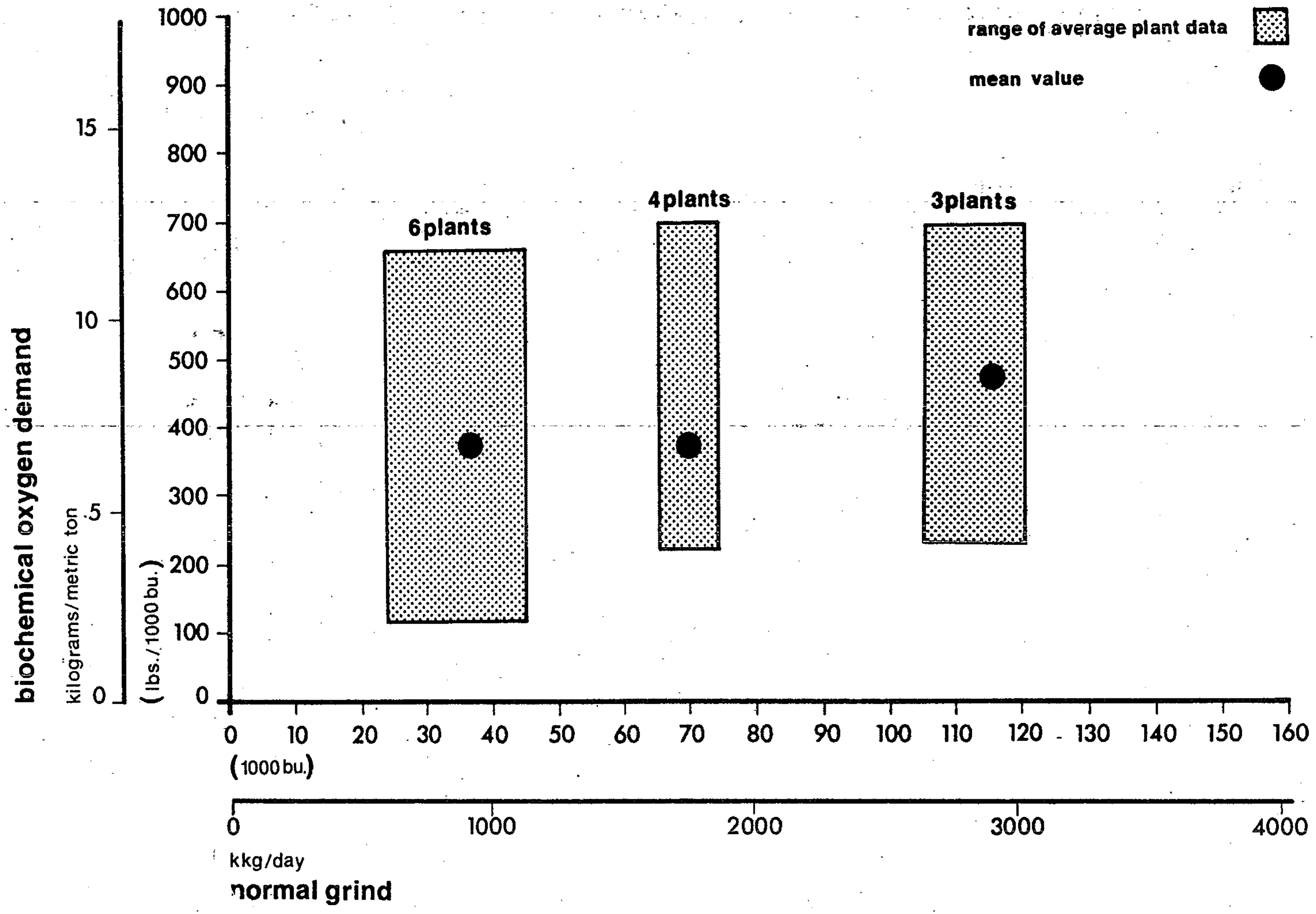

FIGURE 12
AVERAGE BOD DISCHARGED AS A FUNCTION OF CORN WET MILL CAPACITY

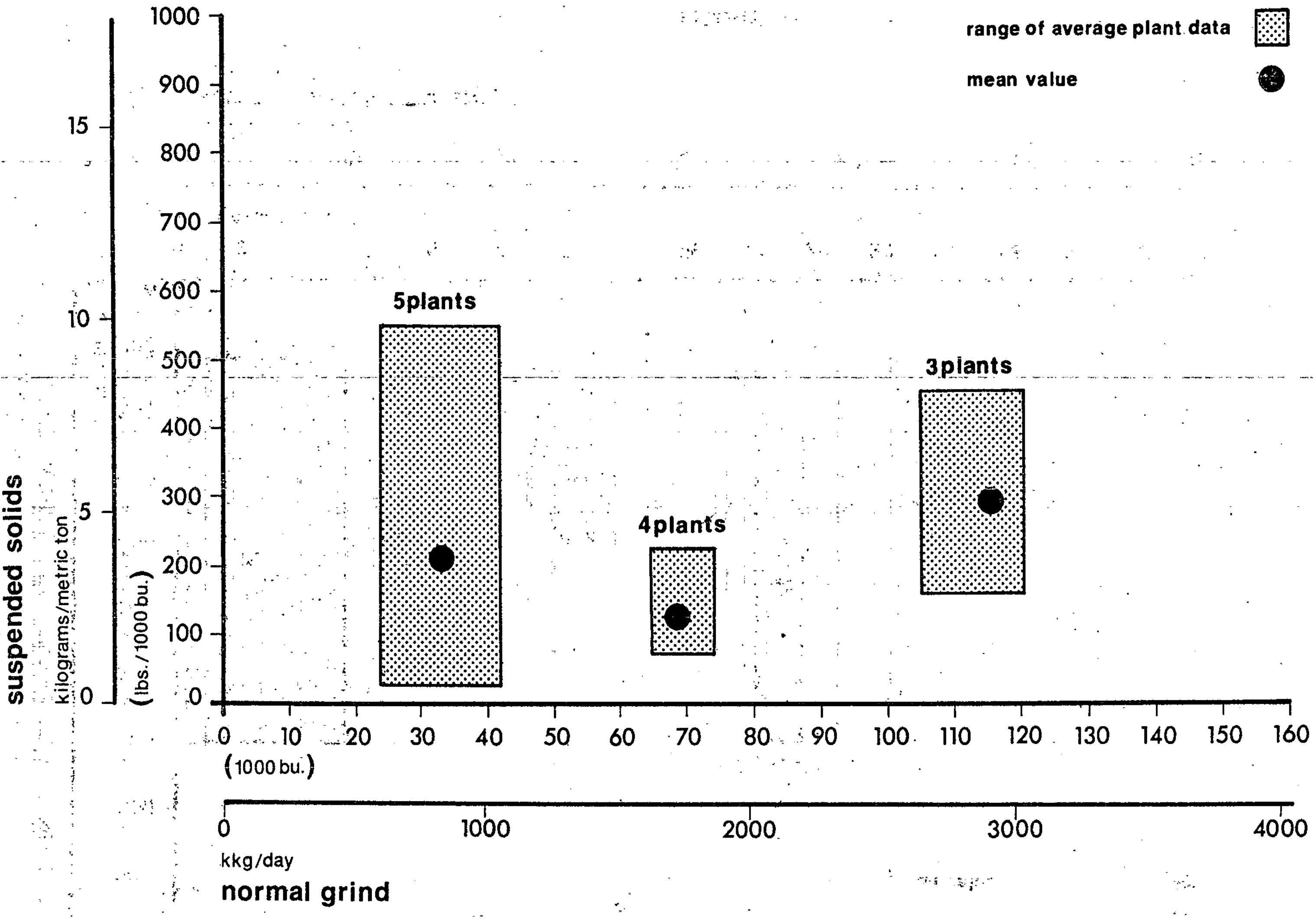

FIGURE 13

AVERAGE SUSPENDED SOLIDS DISCHARGED AS A FUNCTION OF CORN WET MILL CAPACITY

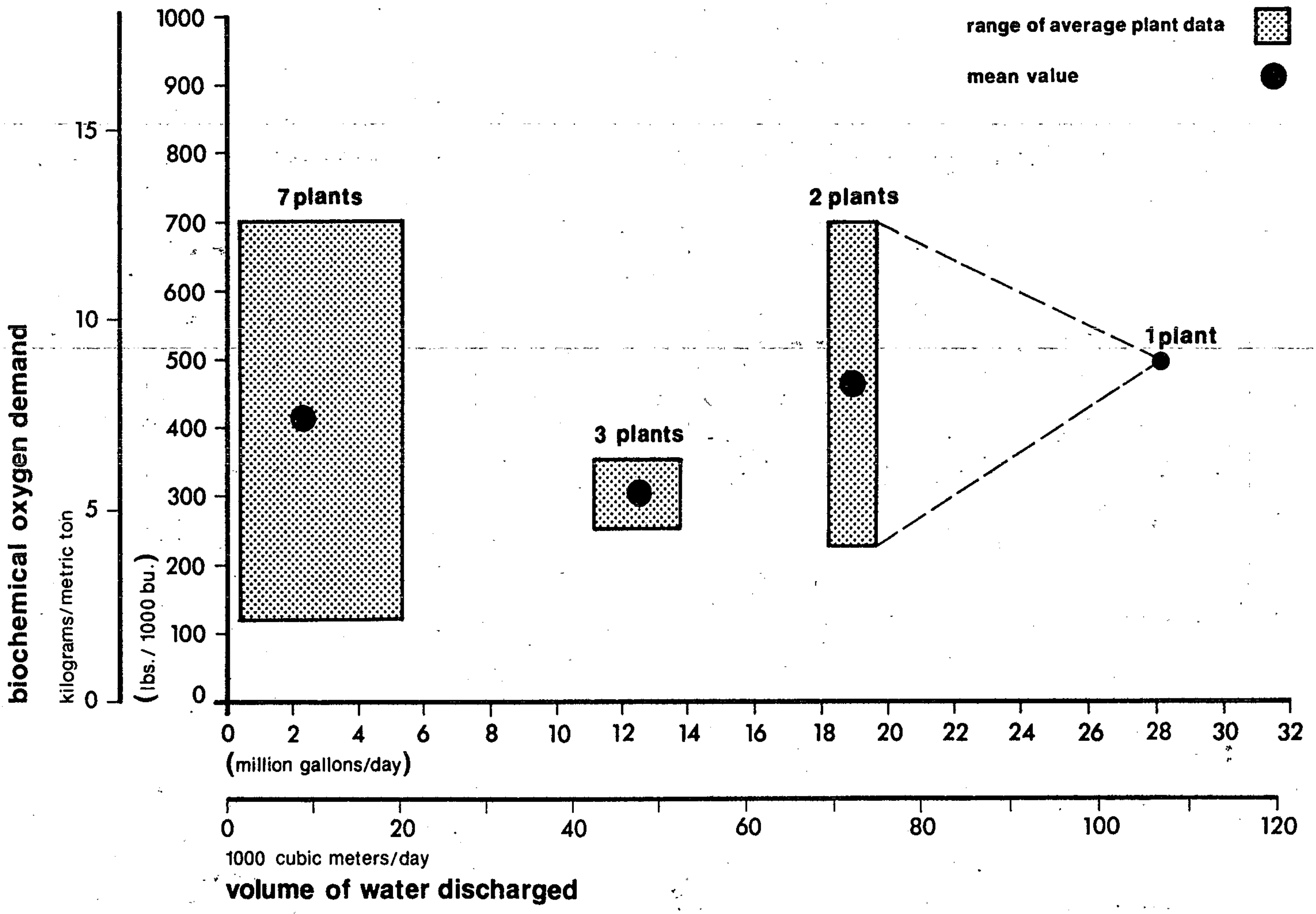

FIGURE 14

AVERAGE BOD DISCHARGED AS A FUNCTION OF WASTEWATER VOLUME

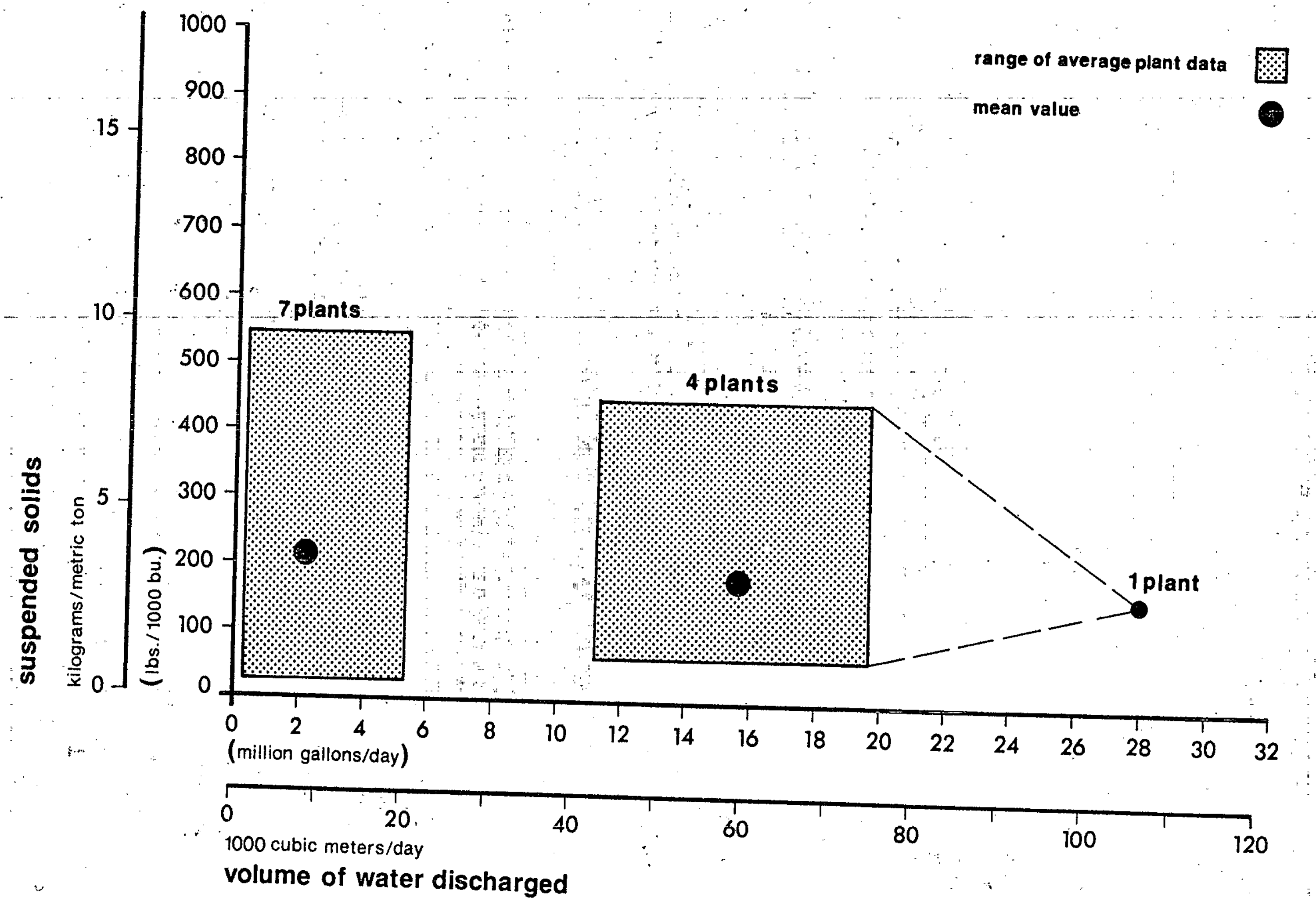

FIGURE 15
AVERAGE SUSPENDED SOLIDS AS A FUNCTION OF WASTEWATER VOLUME

this is not universally the case. Clearly, careful monitoring and control of process operations will reduce spills and, hence, the total amounts of waste discharged. The effect of good housekeeping and operational controls is difficult to quantify, although some industry sources indicate that waste reductions of 20 to 30 percent, or more, can be achieved through these measures.

Summary-

In summary, no quantitative relationships could be established between the total plant raw waste loads and such factors as plant size, age, product mix, water use, and operational procedures. At the same time, it is important to recognize that many of these considerations will, indeed, influence the character of the total waste discharges.

CORN DRY MILLING

Water Use

Water use in corn dry milling is generally limited to corn washing, tempering, and cooling, as shown on the product flow diagram presented earlier, Figure 2. Not all mills use water to clean the corn, probably, because the resultant waste waters constitute a pollution problem. It is believed that most of the larger mills, however, do wash the corn although data on the number of such installations is not available. Water use for this purpose ranges from about 0.45 to 1.2 cu m/kkg (3 to 8 gal/SBu).

After washing, water is added to the corn to raise the moisture content to about 21 to 25 percent in order to make it more suitable for subsequent milling. Only enough water is added in this operation to reach the desired moisture content and no waste water is generated.

Waste Water Characteristics

Other than infrequent car washing, the only process waste water in corn dry milling is that originating from the washing of corn. Data on raw waste characteristics from three plants are presented in Table 12. In one instance, the plant, also, processes soybeans and the waste waters are combined. This same mill generates some waste water from air pollution control equipment (wet scrubbers) on corn and soybean processing systems. These wastes are excluded from the data in Table 12, inasmuch, as they originate from secondary processing of milled corn rather than the basic milling sequence covered in this document.

Average waste water discharges from the three mills range from about 0.48 to 0.9 cu m/kkg (3200 to 6000 gal/MSBu). The waste waters are characterized by high BOD5 and suspended solids

Table 12
Wastewater Characteristics
Corn Dry Milling

Plant	Flow		BOD	COD	Suspended Solids	pH	Phosphorus as P	Total Nitrogen as N
	cu m/day	gals/day	mg/l	mg/l	mg/l		mg/l	mg/l
1	227	60,000	900	-	1,522	-	-	-
2	900	238,000	603	1,795	1,038	7.8	-	-
3	818	216,000	2,748	4,901	3,485	3.7	43.0	13.2

concentrations. The raw waste water BOD5 values average 1.14 kg/kkg (64 lbs/MSBu), and the suspended solids average 1.62 kg/kkg (91 lbs/MSBu).

Factors Affecting Waste Water Characteristics

Insufficient data were available to establish any relationships between waste water characteristics and such factors as plant age, size, and operating procedures. Clearly the size of plant and the type and cleanliness of the corn will influence both the flow and waste characteristics, but in ways that cannot be defined at this time.

WHEAT MILLING

The normal milling of wheat into flour uses water only in tempering and cooling and no process waste waters are discharged. A few normal flour mills do wash the wheat, but the vast majority use dry cleaning techniques. Accordingly, the remainder of this discussion will concentrate on bulgur production.

Water Use

As indicated in the product flow diagram, Figure 4, water is added to the wheat in the soaking operation. Depending on the specific process employed, water may be added at as many as four locations, all, essentially, relating to the same soaking operation. Water usage for typical bulgur plants ranges from about 115 to 245 cu m/day (30,000 to 65,000 gpd). Most of this water is used to raise the moisture content of the wheat from 12 percent, as received, to about 42 percent.

Waste Water Characteristics

The only source of process waste water, in the production of bulgur, is from steaming and cooking. As the grain is transferred from bin to bin, water is added on the conveyors and waste water is discharged. The total quantities of waste water from a given bulgur plant are quite small, ranging from 38 to 115 cu m/day (10,000 to 30,000 gpd). Raw waste data from two plants are presented in Table 13. The BOD5 values cited in the accompanying table correspond to an average of about 0.11 kg/kkg (5.9 lbs/MSBu) of BOD5 and 0.10 kg/kkg (5.5 lbs/ MSBu) of suspended solids.

Table 13
Waste Water Characteristics
Bulgur Production

	Concentration mg/l
BOD5	238 - 521
COD	800

Suspended solids	294 - 414
Phosphorus as P	5.6
Total nigrogen as N	3.6
pH	5.8

Factors Affecting Waste Water Characteristics

Factors influencing waste water characteristics undoubtedly include the particular production methods used, type of wheat, and operational procedures. Unfortunately, insufficient data are available to evaluate quantitatively the influence of these factors.

RICE MILLING

The ordinary milling of rice to produce either brown or white rice utilizes no process waters and, hence, generates no waste waters. Water is used in the production of parboiled rice and the remainder of this discussion will focus on this production method.

Water Use

In the parboiled rice process, water is added in the steeping or cooking operation, as shown in the product flow diagram, Figure 6. Water use in the industry varies from about 1.4 to 2.1 cu m/kkg (17 to 25 gal/cwt). Additional water is used in boilers for steam production for the parboiling process. At least one plant uses wet scrubbers for dust control, thereby, generating an additional source of waste water.

Raw Waste Water Characteristics

Limited data are available on raw waste water characteristics from rice parboiling. The information that is available is summarized in Table 14. The raw waste loads presented in the table correspond to 1.8 kg/kkg (0.18 lbs/cwt) of BOD5 and 0.07 kg/kkg (0.007 lbs/cwt) of suspended solids. In general, the waste may be characterized as having a high soluble BOD5 content and a low suspended solids level.

Table 14
Waste Water Characteristics
Parboiled Rice Milling

	Concentration mg/l
BOD5	1280 - 1305
COD	2810 - 3271
Suspended solids	33 - 77
Dissolved solids	1687

Phosphorus as P	98
Total nitrogen as N	7.0

Factors Affecting Waste Water Characteristics

Based on the very limited amount of data available, it appears that the waste characteristics from parboiled rice plants are quite similar. While there are some differences in flow volumes, the total waste loads per unit of production are similar.

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

The waste water parameters which can be used in characterizing the process waste waters from the grain milling industry are as follows: BOD5 (5-day), suspended solids, pH, COD, dissolved solids, nitrogen, phosphorous, and temperature. These parameters are common to the entire industry but are not always of equal importance. As described below, the selection of the waste water control parameters was determined by the significance of the parameters and the availability of data throughout each industry subcategory.

MAJOR CONTROL PARAMETERS

The following selected parameters are the most important characteristics in grain milling wastes. Data collected during the preparation of this document was limited in most cases to these parameters. Nevertheless, the use of these parameters adequately describes the waste water characteristics from virtually all plants in the industry. BOD5 (5-day), suspended solids, and pH are, therefore, the parameters selected for effluent limitations guidelines and standards of performance for new sources.

Biochemical Oxygen Demand (BOD5)

Biochemical oxygen demand (BOD) is a measure of the oxygen consuming capabilities of organic matter. The BOD does not in itself cause direct harm to a water system, but it does exert an indirect effect by depressing the oxygen content of the water. Sewage and other organic effluents during their processes of decomposition exert a BOD, which can have a catastrophic effect on the ecosystem by depleting the oxygen supply. Conditions are reached frequently where all of the oxygen is used and the continuing decay process causes the production of noxious gases such as hydrogen sulfide and methane. Water with a high BOD indicates the presence of decomposing organic matter and subsequent high bacterial counts that degrade its quality and potential uses.

Dissolved oxygen (DO) is a water quality constituent that, in appropriate concentrations, is essential not only to keep organisms living but also to sustain species reproduction, vigor, and the development of populations. Organisms undergo stress at reduced D.O. concentrations that make them less competitive and able to sustain their species within the aquatic environment. For example, reduced DO concentrations have been shown to interfere with fish population through delayed hatching of eggs, reduced size and vigor of embryos, production of deformities in young, interference with food digestion, acceleration of blood clotting, decreased tolerance to certain toxicants, reduced food efficiency and growth rate, and reduced maximum sustained swimming speed. Fish food organisms are likewise affected adversely in conditions with suppressed DO. Since all aerobic aquatic organisms need a certain amount of oxygen, the consequences of total lack of dissolved oxygen due to a high BOD can kill all inhabitants of the affected area.

If a high BOD is present, the quality of the water is usually visually degraded by the presence of decomposing materials and algae blooms due to the uptake of degraded materials that form the foodstuffs of the algal populations.

BOD_5 is an important and widely accepted measure of the biodegradability of organic matter in waste waters. Most plants routinely measure BOD_5 in their waste waters. Typical BOD_5 levels in all of the subcategories are quite high, ranging from several hundred to several thousand mg/l. Discharge of such wastes to surface waters can result in oxygen depletion and damage to aquatic life.

Suspended Solids (SS)

Suspended solids include both organic and inorganic materials. The inorganic components include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, animal and vegetable fats, various fibers, sawdust, hair, and various materials from sewers. These solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. They adversely affect fisheries by covering the bottom of the stream or lake with a blanket of material that destroys the fish-food bottom fauna or the spawning ground of fish. Deposits containing organic materials may deplete bottom oxygen supplies and produce hydrogen sulfide, carbon dioxide, methane, and other noxious gases.

In raw water sources for domestic use, state and regional agencies generally specify that suspended solids in streams shall not be present in sufficient concentration to be objectionable or to interfere with normal treatment processes. Suspended solids in water may interfere with many industrial processes, and cause foaming in boilers, or encrustations on equipment exposed to water, especially as the temperature rises. Suspended solids are undesirable in water for textile industries; paper and pulp; beverages; dairy products; laundries; dyeing; photography; cooling systems, and power plants. Suspended particles also serve as a transport mechanism for pesticides and other substances which are readily sorbed into or onto clay particles.

Solids may be suspended in water for a time, and then settle to the bed of the stream or lake. These settleable solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration and impair the photosynthetic activity of aquatic plants.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, they are often much more damaging to the life in water, and they retain the capacity to displease the senses. Solids, when transformed to sludge deposits, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. When of an organic and therefore decomposable nature, solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a seemingly inexhaustible food source for sludgeworms and associated organisms.

Turbidity is principally a measure of the light absorbing properties of suspended solids. It is frequently used as a substitute method of quickly estimating the total suspended solids when the concentration is relatively low.

The suspended solids levels of the raw waste waters, in most segments of this industry, are quite high, ranging from about 500 to 3500 mg/l. Parboiled rice mills and specific plants in other subcategories, may have substantially lower suspended solids levels. The very high suspended solids level common to the industry, however, may constitute a serious pollution problem if discharged to surface waters. Moreover, the solids are generally finely divided grain particles and represent a sizable fraction of the organic load in the wastewater.

pH, Acidity and Alkalinity

Acidity and alkalinity are reciprocal terms. Acidity is produced by substances that yield hydrogen ions upon hydrolysis and alkalinity is produced by substances that yield hydroxyl ions. The terms "total acidity" and "total alkalinity" are often used to express the buffering capacity of a solution. Acidity in natural waters is caused by carbon dioxide, mineral acids, weakly dissociated acids, and the salts of strong acids and weak bases. Alkalinity is caused by strong bases and the salts of strong alkalies and weak acids.

The term pH is a logarithmic expression of the concentration of hydrogen ions. At a pH of 7, the hydrogen and hydroxyl ion concentrations are essentially equal and the water is neutral. Lower pH values indicate acidity while higher values indicate alkalinity. The relationship between pH and acidity or alkalinity is not necessarily linear or direct.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add such constituents to drinking water as iron, copper, zinc, cadmium and lead. The hydrogen ion concentration can affect the "taste" of the water. At a low pH water tastes "sour". The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7. This is very significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Dead fish, associated algal blooms, and foul stenches are aesthetic liabilities of any waterway. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. Metalocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units. The availability of many nutrient substances varies with the alkalinity and acidity. Ammonia is more lethal with a higher pH.

The lacrimal fluid of the human eye has a pH of approximately 7.0 and a deviation of 0.1 pH unit from the norm may result in eye irritation for the swimmer. Appreciable irritation will cause severe pain.

The pH levels in the wastes from the various subcategories covered in this document vary appreciably. Generally, the waste waters tend to be neutral or slightly acidic. Under certain conditions, in some wet corn mills, the combined waste stream may be very acid or quite alkaline at different times. pH is an essential control parameter for treatment of the waste and regulation of the discharges.

ADDITIONAL PARAMETERS

Chemical Oxygen Demand (COD)

COD is a chemical measure of the organic content and, hence, oxygen demand, of the waste water constituents. As with most food wastes, the COD is considerably higher than the BOD, usually by a factor of 1.5 to 2.0 Several companies in the grain milling industry rely on COD as a much more rapid measure of the organic content than BOD, and use it as a rapid monitoring technique for the waste. In most instances, the ratio of COD to BOD5 in the raw waste can be established for a given plant and COD can serve as an excellent control parameter. However, the COD data collected during the preparation of this report was sparse. No definitive relationship between COD and BOD5 (5-day) can be established at the present time. The fact that the chemical nature of the organics may differ from plant to plant may preclude the use of a uniform COD standard for each subcategory. Therefore, it was concluded that effluent limitations guidelines and standards of performance could not be determined for COD.

Inorganic Dissolved Solids

In natural waters the dissolved solids consist mainly of carbonates, chlorides, sulfates, phosphates, and possibly nitrates of calcium, magnesium, sodium, and potassium, with traces of iron, manganese and other substances.

Many communities in the United States and in other countries use water supplies containing 2000 to 4000 mg/l of dissolved salts, when no better water is available. Such waters are not palatable, may not quench thirst, and may have a laxative action on new users. Waters containing more than 4000 mg/l of total salts are generally considered unfit for human use, although in hot climates such higher salt concentrations can be tolerated whereas they could not be in temperate climates. Waters containing 5000 mg/l or more are reported to be bitter and act as bladder and intestinal irritants. It is generally agreed that the salt concentration of good, palatable water should not exceed 500 mg/l.

Limiting concentrations of dissolved solids for fresh-water fish may range from 5,000 to 10,000 mg/l, according to species and prior acclimatization. Some fish are adapted to living in more saline waters, and a few species of fresh-water forms have been found in natural waters with a salt concentration of 15,000 to 20,000 mg/l. Fish can slowly become acclimatized to higher salinities, but fish in waters of low salinity cannot survive sudden exposure to high salinities, such as those resulting from discharges of oil-well brines. Dissolved solids may influence the toxicity of heavy metals and organic compounds to fish and other aquatic life, primarily because of the antagonistic effect of hardness on metals.

Waters with total dissolved solids over 500 mg/l have decreasing utility as irrigation water. At 5,000 mg/l water has little or no value for irrigation.

Dissolved solids in industrial waters can cause foaming in boilers and cause interference with cleaness, color, or taste of many finished products. High contents of dissolved solids also tend to accelerate corrosion.

Specific conductance is a measure of the capacity of water to convey an electric current. This property is related to the total concentration of ionized substances in water and water temperature. This property is frequently used as a substitute method of quickly estimating the dissolved solids concentration.

There are a number of sources of inorganic dissolved solids in the various subcategories of the grain milling industry. These include wastes from water treatment, cooling water blowdown, deionizer regeneration and various processes in the plant. The increase of dissolved solids in the waste waters were not found to large. Moreover, the sources of inorganics mentioned above are in many cases common to other industries. Since these problems are difficult to handle practically and economically, EPA will consider effluent guidelines for these sources at a later data, and they are not discussed in this report.

Temperature

Temperature is one of the most important and influential water quality characteristics. Temperature determines those species that may be present; it activates the hatching of young, regulates their activity, and stimulates or suppresses their growth and development; it attracts, and may kill when the water becomes too hot or becomes chilled too suddenly. Colder water generally suppresses development. Warmer water generally accelerates activity and may be a primary cause of aquatic plant nuisances when other environmental factors are suitable.

Temperature is a prime regulator of natural processes within the water environment. It governs physiological functions in organisms and, acting directly or indirectly in combination with other water quality constituents, it affects aquatic life with each change. These effects include chemical reaction rates, enzymatic functions, molecular movements, and molecular exchanges between membranes within and between the physiological systems and the organs of an animal.

Chemical reaction rates vary with temperature and generally increase as the temperature is increased. The solubility of gases in water varies with temperature. Dissolved oxygen is decreased by the decay or decomposition of dissolved organic substances and the decay rate increases as the temperature of the water increases reaching a maximum at about 30°C (86°F). The temperature of stream water, even during summer, is below the optimum for pollution-associated bacteria. Increasing the water temperature increases the bacterial multiplication rate when the environment is favorable and the food supply is abundant.

Reproduction cycles may be changed significantly by increased temperature because this function takes place under restricted temperature ranges. Spawning may not occur at all because temperatures are too high. Thus, a fish population may exist in a heated area only by continued immigration. Disregarding the decreased reproductive potential, water temperatures need not reach lethal levels to decimate a species. Temperatures that favor competitors, predators, parasites, and disease can destroy a species at levels far below those that are lethal.

Fish food organisms are altered severely when temperatures approach or exceed 90°F. Predominant algal species change, primary production is decreased, and bottom associated organisms may be depleted or altered drastically in numbers and distribution. Increased water temperatures may cause aquatic plant nuisances when other environmental factors are favorable.

Synergistic actions of pollutants are more severe at higher water temperatures. Given amounts of domestic sewage, refinery wastes, oils, tars, insecticides, detergents, and fertilizers more rapidly deplete oxygen in water at higher temperatures, and the respective toxicities are likewise increased.

When water temperatures increase, the predominant algal species may change from diatoms to green algae, and finally at high temperatures to blue-green algae, because of species temperature preferentials. Blue-green algae can cause serious odor problems. The number and distribution of benthic organisms decreases as water temperatures increase above 90°F, which is close to the tolerance limit for the population. This could seriously affect certain fish that depend on benthinc organisms as a food source.

The cost of fish being attracted to heated water in winter months may be considerable, due to fish mortalities that may result when the fish return to the cooler water.

Rising temperatures stimulate the decomposition of sludge, formation of sludge gas, multiplication of saprophytic bacteria and fungi (particularly in the presence of organic wastes), and the consumption of oxygen by putrefactive processes, thus, affecting the esthetic value of a water course.

In general, marine water temperatures do not change as rapidly or range as widely as those of freshwaters. Marine and estuarine fishes, therefore, are less tolerant of temperature variation. Although this limited tolerance is greater in estuarine than in open water marine species, temperature changes are more important to those fishes in estuaries and bays than to those in open marine areas, because of the nursery and replenishment functions of the estuary that can be adversely affected by extreme temperature changes.

Many operations in grain milling inherently elevate the temperatures of the resultant process waste streams. This is especially true where steeping, soaking, or cooking processes are used, such as in wet corn milling, bulgur production, and parboiled rice manufacture. Direct contact barometric cooling water is a major source of heated waste water in some corn wet mills. Temperatures from selected waste streams and in some instances from combined total plant wastes, sometimes approach 38 degrees C (100 degrees F). Elimination of once through barometric condenser water by the use of cooling towers will significantly reduce this problem. The blowdown from the cooling tower will be discharged to the treatment plant where it will either be cooled prior to treatment or in the treatment process itself. Non-contact cooling water is a separate industrial category for which EPA will address and issue guidelines at a later date. Therefore, temperature was not selected as a control parameter for the purposes of this report.

Phosphorus

During the past 30 years, a formidable case has developed for the belief that increasing standing crops of aquatic plant growths, which often interfere with water uses and are nuisances to man, frequently are caused by increasing supplies of phosphorus. Such phenomena are associated with a condition of accelerated eutrophication or aging of waters. It is generally recognized that phosphorus is not the sole cause of eutrophication, but there is evidence to substantiate that it is frequently the key element in all of the elements required by fresh water plants and is generally present in the least amount relative to need. Therefore, an increase in phosphorus allows use of other, already present, nutrients for plant growths. Phosphorus is usually described, for this reasons, as a "limiting factor."

When a plant population is stimulated in production and attains a nuisance status, a large number of associated liabilities are immediately apparent. Dense populations of pond weeds make swimming dangerous. Boating and water skiing and sometimes fishing may be eliminated because of the mass of vegetation that serves as an physical impediment to such activities. Plant populations have been associated with stunted fish populations and with poor fishing. Plant nuisances emit vile stenches, impart tastes and odors to water supplies, reduce the efficiency of industrial and municipal water treatment, impair aesthetic beauty, reduce or restrict resort trade, lower waterfront property values, cause skin rashes to man during water contact, and serve as a desired substrate and breeding ground for flies.

Phosphorus in the elemental form is particularly toxic, and subject to bioaccumulation in much the same way as mercury. Colloidal elemental phosphorus will poison marine fish (causing skin tissue breakdown and discoloration). Also, phosphorus is capable of being concentrated and will accumulate in organs and soft tissues. Experiments have shown that marine fish will concentrate phosphorus from water containing as little as 1 ug/l.

Phosphorus levels in corn wet milling waste waters generally appear to be quite low. The data on other subcategories indicate that levels of some significance may be present in the wastes. In particular, corn dry milling and parboiled rice production appear to generate high concentrations of phosphorus ranging from about 30 to 65 mg/l. This information is based on limited data, and is not sufficient to determine effluent limitations.

Ammonia

Ammonia is a common product of the decomposition of organic matter. Dead and decaying animals and plants along with human and animal body wastes account for much of the ammonia entering the aquatic ecosystem. Ammonia exists in its non-ionized form only at higher pH levels and is the most toxic in this state. The lower the pH, the more ionized ammonia is formed and its toxicity decreases. Ammonia, in the presence of dissolved oxygen, is converted to nitrate (NO_3) by nitrifying bacteria.

Nitrite (NO_2), which is an intermediate product between ammonia and nitrate, sometimes occurs in quantity when depressed oxygen conditions permit. Ammonia can exist in several other chemical combinations including ammonium chloride and other salts.

Nitrates are considered to be among the poisonous ingredients of mineralized waters, with potassium nitrate being more poisonous than sodium nitrate. Excess nitrates cause irritation of the mucous linings of the gastrointestinal tract and the bladder; the symptoms are diarrhea and diuresis, and drinking one liter of water containing 500 mg/l of nitrate can cause such symptoms.

Infant methemoglobinemia, a disease characterized by certain specific blood changes and cyanosis, may be caused by high nitrate concentrations in the water used for preparing feeding formulae. While it is still impossible to state precise concentration limits, it has been widely recommended that water containing more than 10 mg/l of nitrate nitrogen (NO_3-N) should not be used for infants. Nitrates are also harmful in fermentation processes and can cause disagreeable tastes in beer. In most natural water the pH range is such that ammonium ions (NH_4^+) predominate. In alkaline waters, however, high concentrations of un-ionized ammonia in undissociated ammonium hydroxide increase the toxicity of ammonia solutions. In streams polluted with sewage, up to one half of the nitrogen in the sewage may be in the form of free ammonia, and sewage may carry up to 35 mg/l of total nitrogen. It has been shown that at a level of 1.0 mg/l un-ionized ammonia, the ability of hemoglobin to combine with oxygen is impaired and fish may suffocate. Evidence indicates that ammonia exerts a considerable toxic effect on all aquatic life within a range of less than 1.0 mg/l to 25 mg/l, depending on the pH and dissolved oxygen level present.

Ammonia can add to the problem of eutrophication by supplying nitrogen through its breakdown products. Some lakes in warmer climates, and others that are aging quickly are sometimes limited by the nitrogen available. Any increase will speed up the plant growth and decay process.

Nitrogen levels of the wastes have been measured throughout the industry and generally tend to be below 20 mg/l, usually below 10 mg/l. These levels may be necessary to achieve good biological treatment. However, no information is available to determine this requirement, nor to determine effluent limitations.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

INTRODUCTION

Except in the corn wet milling industry, little attention has been focused on either in-plant control or treatment of the wastewaters. Many of the mills discharge to municipal systems while the waste waters from other plants flow into large rivers where the impact has not been of great concern until recently. Only in corn wet milling has considerable attention been focused on both in-plant control and end-of-process treatment. The emphasis on waste water control in this segment of the industry is, of course, a reflection of the large quantities of waste waters discharged in contrast to the much smaller amounts generated by other types of grain milling. In many instances, the treatment technologies developed for corn wet milling can be transferred to the other industry subcategories.

CORN WET MILLING

Waste Water Characteristics

As developed in detail in Section V, the waste waters from corn wet mills contain large amounts of BOD5 and suspended solids. Depending on the type of cooling water system employed, the concentrations of these constituents range from moderate to high. Most plants have isolated their major waste streams into a concentrated stream for treatment. Once-through cooling water systems are being replaced with recirculating systems, in several instances.

In concentrating the waste streams, the mills have reduced the volume of water to be treated and, hence, the cost of treatment, but have increased the operational difficulty of achieving low effluent concentrations. In essence, it is much more difficult to reduce a raw waste BOD5 of 1,000 mg/l to an effluent of 30 mg/l than it is to reduce an influent BOD5 of 250 mg/l to the same 30 mg/l.

In evaluating waste water control in the corn wet milling industry, it is essential to evaluate both in-plant control measures and effluent treatment systems. Good in-plant controls can greatly reduce the total raw waste load and improve treatment plant efficiency.

In-Plant Control Measures

All corn wet mills presently incorporate many water recycling and reuse techniques. In the early days of corn wet mills, little if any water conservation or by-product recovery was practiced.

Through research, new markets were found for materials that were once wasted, such as steepwater. Efforts to improve product recovery and simultaneously to reduce waste discharges, have led to innovative process operations which utilize recycled water wherever possible and generally incorporate up-to-date process technology.

The degree of in-plant control practiced by individual mills reflects many factors, not the least of which are the physical constraints of the existing facility. The physical space available in the plant may prevent the installation of certain types of in-plant controls, such as holding tanks for overflows. While physical constraints are not necessarily a reflection of plant age, many process controls difficult to implement in older plants have been incorporated into the construction of new mills. In the following paragraphs, a number of in-plant modifications involving water conservation and/or waste reduction are suggested. Many of these have been incorporated in one or more plants in the industry, but the ability to implement any of them must be evaluated for each individual plant.

Cooling Systems-

The cooling systems used in this industry can be characterized as non-contact cooling surface condensers and contact cooling (barometric condensers). They can be further subdivided into once-through and recirculating systems. Since non-contact cooling water, both once through and recirculated are common to many other industries, EPA will issue guidelines on the non-contact cooling water area at a later date. This report concerns itself with organic contamination of both contact cooling water (barometric condenser) water and condensates from surface condensers.

One of the major waste loads from any corn mill is the condensate from steepwater and syrup evaporators. Where surface condensers are employed, the condensate is discharged as a concentrated waste stream, suitable for treatment. Many plants use barometric condensers on the evaporators and the resultant condensate is comingled with the cooling waters, resulting in large volumes of dilute waste. Because of the large volume and low concentration, the removal of entrained BOD_5 and suspended solids is both expensive and difficult if once-through cooling waters are used.

There are two possible remedies to this problem and both are being implemented by various companies in the industry. One approach is to convert all barometric condensers to surface condensers, but this solution is not always practical. Physical restraints in some plants prevent the installation of large surface condensers. Moreover, such condensers are expensive and generally require more maintenance than barometric condensers. In spite of these difficulties, several plants have converted many of their barometric condensers to surface units.

An alternate approach, also being employed by several companies, is to recirculate the barometric cooling water over cooling towers. In this manner, the waste volume is reduced to the blowdown from the cooling system and is much more concentrated than in the once-through system. Moreover, physical and biological processes active in the cooling tower effect some reduction in the total BOD5 load from the evaporators.

Operational Control of Evaporators-

The control exercised in the operation of steepwater and syrup evaporators can have a significant effect on the total organic carryover in the condensate. From a waste reduction standpoint, two problems are prevalent in evaporator operation. The emphasis in operation is on obtaining maximum steepwater or syrup throughput in the evaporators and not on minimizing organic carry-over. Accordingly, a number of plants operated their evaporators at very heavy loading rates, rates which are not commensurate with good waste control. Lack of careful control by the operators is a second evaporator operational problem. Both situations lead to the frequent boiling over of the liquor and resultant heavy waste discharges. Improved operator control and expanded evaporator capacity can greatly reduce these problems.

Improved Evaporator Demisters-

The amount of organic carry-over from evaporators can also be reduced by installing modern entrainment separators or demisting devices. Many plants have already incorporated better entrainment separators and research continues on ways to reduce organic carry-over even further. It is also important that this type of equipment be well maintained.

Reuse of Process Waste Waters-

Although major recycling and reuse of process waste waters is practiced at all corn wet mills, additional recycling is possible at most plants and will have a significant effect on total waste effluent. At the same time it must be recognized that the extent of reuse is subject to restraints imposed by the Food and Drug Administration regarding good manufacturing practices for food processing. Typically, fresh water enters the milling operation in the starch washing, and waste waters from ordinary and lightly modified starches is reused in numerous processes in the starch, feed, and mill houses. In these three areas of the plant, waste waters are primarily generated only from the washing of modified starches and from steepwater evaporation.

Water reuse practices in the refinery area vary considerably from mill to mill. In many plants, waste waters are sewered from syrup cooling, enzyme production, carbon treatment, ion exchange regeneration, syrup evaporation, dextrose production, and syrup shipping. At least some of these wastes are lightly contaminated and suitable for reuse. For example, at some mills condensate and syrup evaporation is used as input water for activated carbon and ion exchange washing and regeneration. Such practice not only greatly reduces total water use in the refinery, but also decreases the total waste load from these operations. In essence, product recovery is increased by this type of water reuse.

Improved Solids Recovery-

Screens, filters, and centrifugal separating equipment can be used to recover solids from waste streams directly at their source. For example, centrifugal devices can be used on starch filtrate streams to recover solids passing through holes that develop in the filter media. Such solids can then be returned directly as product. In some mills, filters or screens are used in the gluten processing area to recover solids during start-up and shut-down activities and return these solids to by-product recovery.

Waste waters from the finished starch department, exclusive of highly modified starch wastes, can be directed to a clarifier or thickener to accomplish additional solids recovery. Rather substanital quantities of solids can be recovered by this method and returned either to process or sold directly as mill starch. Several mills have used settling tanks for this purpose for many years.

Containment of Overflows and Spills-

In a typical corn wet mill, overflows and spills from various pieces of equipment occur quite frequently. When sewered directly, these spills constitute a large waste source. Although good operation can minimize the frequency and amount of such process upsets, they cannot be eliminated and in-plant provisions should be made to contain these waste water.

Specifically, those areas prone to upsets should be diked and sumps or monitoring tanks installed in the area to retain the overflows. The floor spillage can then be discharged gradually to these sewer, thus reducing shock loads on the waste treatment system.

In new plants, the specific equipment overflows can be piped directly to monitoring tanks and floor spillage largely eliminated. This same practice can be instituted in existing plants, but to a more limited degree. Once the overflows have been contained, their contents can be analyzed and decisions made as to whether the material can be recycled back into the process, discharged to by-product recovery, or if absolutely necessary, discharged to the sewer. Such monitoring controls are used by a few plants in the industry and have proved very effective in reducing total plant waste discharges. Simultaneously, they have the added benefit of improving general plant housekeeping.

Monitoring of Process Wastes-

Perhaps the most effective means of reducing overall plant waste loads is to institute a careful monitoring program of all major process waste streams. Such a program involves frequent sampling of the waste streams and analysis for both product losses and waste load. Initially, the program will identify the major sources of wastes and permit production personnel to correct any process deficiencies thereby reducing, and perhaps eliminating, many waste sources.

The effectiveness of such a monitoring program is limited by the importance attached to it by company management. Where management has recognized the need for reducing waste discharges and has supported the monitoring effort, very substantial reductions in the quantities of pollutants discharged have been realized. Commensurate with this waste reduction has been increased product recovery, which at least partially offsets the cost of the monitoring.

General Plant Operation and Housekeeping-

As in many industries, general operational and housekeeping procedures have a marked effect on the amount of wastes discharged. Those plants practicing close operational control and good housekeeping tend to generate far less wastes than plants at the opposite extreme. Once again, the impetus for improving operational and housekeeping procedures must come from top management if it is to be effective.

Effects and Costs of In-Plant Control-

Because of the unique nature of each plant in this subcategory, it is impossible to estimate the overall effect on total waste discharge achieved by instituting the above in-plant modifications. In general terms, it is likely that total waste loads can be reduced by 25 percent or more by these activities in plants where they are not practiced at this time.

It is equally difficult to quantify the costs associated with effecting these in-plant controls, inasmuch as the needs and the equipment costs will vary for each plant. These costs will have to be evaluated on an individual plant basis, taking into account various alternatives, plant layout, physical restraints, and other factors.

Treatment Processes

Of the seventeen plants in the industry, at least seven provide some type of treatment or pretreatment of the plant effluent. There are three activated sludge systems in operation that discharge directly to surface waters and one additional system that is under construction. Three activated sludge pretreatment plants discharge to municipal systems and a unique fungal digestion pretreatment plant is under construction at a fourth plant. More limited pretreatment, consisting of settling and some aeration, is provided at another plant. Pilot plant studies were conducted on the joint treatment of municipal and corn wet milling wastes using the pure oxygen system and a full-scale treatment facility plant is now under construction. The various treatment systems that are in use and the results of two pilot plant studies are described below.

Complete Treatment-

Three corn milling plants have waste treatment facilities that discharge treated effluent directly to the receiving waters. Each of these plants is of the activated sludge type, although they vary somewhat in their detailed process operations.

Plant A--Waste treatment Plant A handles about 2,460 cu m/day (650,000 gpd) of concentrated wastes from a medium-sized corn wet mill. The treatment plant does not receive the large quantities of once-through cooling water used at the plant, and which contain relatively low concentrations of BOD5 and suspended solids. The waste water influent to the treatment plant contains over 3,000 mg/l of COD and 700 mg/l of suspended solids.

The treatment sequence itself consists of complete-mix activated sludge, secondary clarification, aeration in two lagoons operated in series, and clorination. No primary clarification is provided in this system. The activated sludge basin provides up to 48 hours detention, and the two lagoons following the secondary clarifier provide up to 16 days additional retention. The first of the lagoons is fully aerated, while the last portion of the second basin is quiescent to provide additional settling.

Effluent characteristics from this treatment facility are as follows:

	Average mg/l	Range mg/l
BOD5	35	6-95
COD	266	102-525
Suspended Solids	169	8-372

The relatively high suspended solids content in the effluent, probably reflects some algae growth in the lagoons. The nature of corn milling wastes, however, tends to generate solids handling problems in treatment systems. At the time of the sampling program at Plant A, the treatment facility was in an upset condition as evidenced by heavily bulking sludge in the secondary clarifier. During this period of time, effluent BOD5 from the treatment plant averaged 444 mg/l with a suspended solids content of 213 mg/l. Such upsets are common to all treatment plants in the corn wet milling industry, and various reasons for them have been hypothesized including shock loads of sugars, specialty starches, and acids or alkalis.

In terms of BOD5 removal, Plant A represents the best treatment in the industry. Suspended solids removal, however, is below expectations.

Plant B--The second plant to be discussed handles the waste from another medium-sized corn wet mill. The facility consists of an aerated equalization basin, two parallel complete-mix activated sludge basins, secondary clarification, and dissolved air flotation. This plant has been the recipient of an Environmental Protection Agency demonstration grant and has been in operation for about two years.

The plant receives a concentrated waste stream of about 3,030 to 3,785 cu m/day (0.8 to 1.0 mgd) containing 1,400 mg/l of BOD, 2,100 mg/l of COD, and 350 mg/l of suspended solids. Once-through cooling water containing some barometric condensate is discharged to the receiving water without treatment.

The aerated equalization basin provides 24-hour retention to equalize waste load and pH fluctuations. In the summer, the discharge in the equalization basin may be passed over a cooling tower in order to reduce the temperature prior to the activated sludge process. Plant B was designed on the basis of a food-to-microorganism ratio of 1.1 to 1.75 in terms of COD:MLSS (mixed liquor suspended solids), and provides about 16-hour detention. The dissolved air flotation following secondary clarification was intended to polish the final effluent by removing any floating biological solid.

The design effluent from the plant is a BOD5 of less than 40 mg/l and a suspended solids content of less than 45 mg/l. Performance to date has been well above these effluent levels, in spite of many modifications to operating procedures. Evaluations by Environmental Protection Agency personnel indicate that the plant was overloaded initially with a food-to-microorganism ratio of 0.8 in terms of BOD:MLSS. Effluent BOD5 and suspended solids were usually several hundred mg/l during the early periods of operation. Efforts by plant personnel have reduced the raw waste loading to the plant and the food-to-microorganism ratio (BOD:MLSS) has now dropped to about 0.4. Effluent characteristics for the last six months of 1972 were as follows:

	Average mg/l	Range mg/l
BOD5	79	5-994
Suspended Solids	142	4-1260

Sampling data taken during this study over a four-day period indicated an effluent BOD5 of 10 mg/l or less and a suspended solids content of about 50 mg/l. The performance of Plant B, particularly during the first three days of the sampling, was exceptionally good and believed to be the best operation yet achieved by this facility. Towards the end of the sample period, however, sludge bulking occurred and the final day's suspended solids analysis was just over 100 mg/l. Plant performance during the week of the sampling program was a graphic illustration of the effect that upsets in this industry can have on treatment efficiency. The equalization basin certainly dampens the effect of shock loads, but upsets still occur frequently.

The performance of Plant B in recent months is a vast improvement over early operations. As the waste load to the plant has been reduced by in-plant modifications, the average effluent quality has improved. Based on the information available about this plant, it appears that future activated sludge systems should be designed with a maximum BOD:MLSS ratio of 0.4 and possibly lower.

Plant C-- the third treatment facility, Plant C, is a new, complete mix activated sludge plant handling about 760 to 1,600 cu m/day (200,000 to 425,000 gpd) of concentrated wet milling wastes from a small mill. The system consists of primary sedimentation, complete-mix activated sludge, and clarification. A cooling tower is provided to reduce the temperature of the wastes during summer months. Influent waste concentrations are about 1,600 mg/l of BOD and 600 mg/l of suspended solids. Because of its newness, only limited data are available on effluent characteristics. Effluent BOD5 levels of 200 to 400 mg/l and suspended solids of 150 to 300 mg/l have been reported. The common problem of solids separation has already appeared at this facility and efforts are apparently underway to control sludge bulking.

Pretreatment Plants-

Of the four known pretreatment plants in the industry, three provide some form of activated sludge treatment prior to discharge to a municipal system. The fourth plant, which will not be discussed in detail, provides some settling and limited aeration.

Plant D--Pretreatment Plant D serves a small mill and consists of two large aerated lagoons that can be operated either in parallel or in series. They provide about 5 days detention for the influent flow which averages about 3,785 cu m/day (1.0 mgd). About seven months of sampling of treatment plant characteristics indicated the following influent and effluent results:

	Average Influent mg/l	Average Effluent mg/l
BOD5	2,330	1,080
COD	4,560	2,870
Suspended Solids	895	2,215

Data taken during the sampling program for this study indicated somewhat lower results on both influent and effluent. These lower effluent values were possibly the result of the recent reactivation of one of the lagoons which had been drained for repairs. In any event, the pretreatment plant provides adequate treatment under the contractual terms with the local municipality. It should be noted that effluent solids from the treatment plant exceed the influent values reflecting the production of biological solids in the system.

Plant E--The second pretreatment plant provides complete-mix activated sludge treatment for a design flow of below 3,785 cu m/day (1.0 mgd) from a small mill. The system consists of two aerated equalization basins with nutrient addition and pH control, followed by a complete-mix activated sludge process, and secondary clarification. This plant is relatively new and has been subject to frequent upsets. Effluent COD and suspended solids are reported to be about 1,000 mg/l and 260 mg/l respectively. In general, the effluent levels are sufficient to meet the pretreatment limitations proposed by the local municipality. Treatment plant efficiency is expected to improve markedly as the production plant operations and, hence, raw waste characteristics stabilize.

Plant F--This pretreatment plant receives the concentrated waste flow from a large corn wet mill. The influent waste flow is about 3,210 cu m/day (0.85 mgd) with a BOD_5 level of about 2,600 mg/l. The facility consists of four aeration basins and secondary clarification prior to discharge to the local municipal system. Certain cooling water and other wastes from the mill do not go through this treatment plant. Effluent levels are reported to be generally in the range of 500 mg/l of BOD. Results of the sampling program were somewhat lower, as given below:

	Average mg/l	Range mg/l
BOD_5	280	68-415
COD	1317	488-2206
Suspended Solids	889	288-1395

Sludge bulking has been a frequent problem at this plant over the years that it has been in operation. The facility itself consists of various aeration basins, some operated in series and others in parallel. Many of the basins have been converted from other prior uses and it is difficult, if not impossible, to extrapolate treatment practices at this plant to the design of new facilities.

Pilot Plant Studies-

At least three new treatment or pretreatment plants are presently under construction. Data on pilot plant studies for two of these are available and discussed below, together with the design parameters for the third plant.

Plant G--Rather extensive pilot plant studies were run, using one- and three-stage pure oxygen and air activated sludge systems, on combined wastes from a medium sized corn wet milling plant and the local municipality. The reported pilot plant data on both plants were somewhat sporadic, particularly in terms of suspended solids removal. Generally, the data demonstrated the applicability of both pure oxygen and air activated sludge systems for the treatment of the combined wastes. The process design consultants have concluded that the pure oxygen system offered certain advantages, particularly in terms of solids handling. Effluent BOD_5 values for the first three months of the oxygen pilot plant usually ranged from 200 to 400 mg/l, but dropped well below 100 mg/l for the last two months of operation. Results with the air system appear to be roughly comparable to those achieved with oxygen.

A full-scale pure oxygen system has been designed and is now under construction to handle the combined municipal and industrial wastes. Design criteria for the plant are for a BOD:MLSS ratio of 0.5 to 0.7 with a MLSS concentration of 3,000 to 4,000 mg/l. There are indications that pure oxygen may offer some advantages in reducing sludge bulking, but the available information throughout the country in related industries does not yet substantiate this hypothesis. Treatment Plant G will certainly provide an adequate test for this theory.

Plant H--This pretreatment plant will receive wastes from a medium sized corn mill. The system is quite unique in that it depends on fungal disgestion as opposed to more conventional biological treatment methods. Pilot plant studies were conducted in a 50,000 gal aerated tank with a detention time of 16 to 24 hours. In order to promote the fungal growth, the system was operated at a pH of 3.5 to 6.0. Influent BOD_5 concentrations ranged from 700 to 4,800 mg/l, with effluent values normally ranging between 100 to 500 mg/l. The mixed liquor suspended solids, in this case the fungal mass, ranged from 500 to 1,800 mg/l.

The results of the pilot plant studies have prompted the company to construct a 3.0 mgd pretreatment plant, based on fungal digestion. The system will consist of 24-hr equalization, pH adjustment, fungal digestion, and final clarification using settling and filtration.

The pilot plant results, while quite interesting, do not appear to indicate any substantial improvement in effluent quality over more conventional biological treatment systems. There may be some advantage in terms of solids handling, inasmuch as the fungal mass apparently can be removed more readily from the final effluent. Plant I--Presently under construction, this treatment plant is designed to handle about 11,355 cu m/day (3.0 mgd) of wastes from a large corn mill. In-plant control measures are being taken to isolate the major waste sources into a concentrated waste stream, which is expected to have a BOD5 content of 1,600 mg/l.

The treatment system will consist of grit and oil removal, nutrient addition and pH control, equalization, cooling over a cooling tower when necessary, a roughing plastic-media trickling filter, activated sludge, secondary clarification, chlorination, and mixed-media filtration.The plant will be the most elaborate treatment facility in the industry and incorporates a great many flexible concepts. The aeration basins are designed on a BOD:MLSS ratio of 0.3 with a total detention time of 18 hours. The roughing filters are designed to remove about 60 percent of the influent BOD5 ahead of the aeration system. The design effluent levels are 5 mg/l of suspended solids and 20 mg/l of BOD. It should be emphasized that these design levels are far below those which have been achieved by any other plant in the corn wet milling or related industries and cannot yet be considered as demonstrated technology.

Sludge Handling

The disposal of suspended and biological solids from the treatment of corn wet milling waste waters constitutes a major problem, as it does for any waste treatment plant handling high-strength organic materials. Experience with waste activated sludge has indicated several methods of disposal which can be applied to corn wet milling. These include dewatering with disposal on land, incineration, or by-product recovery. In this instance, the highly nutritious biological solids potentially provide a material that can be recycled into animal feeds.

Limited information is available on the handling of waste treatment plant sludges in this industry, but it is know that several plants return these solids to the process stream, presumably for animal feed. Several methods for accomplishing this can be suggested including centrifugation, vacuum filtration, and direct addition to evaporators.

It is imperative that sanitary wastes be segregated from process wastes and discharged separately to the municipal system, if biological solids recovery from the process waste treatment plant is to be practiced. Moreover, sterilization by heat or chlorination may be required in some instances. In summary, if the sanitary wastes are separated from process wastes, as they are at most plants, solids from the treatment system can be dewatered and/or recycled directly into the feed house for use in animal feeds.

CORN DRY MILLING

Waste waters from dry corn mills, as detailed in Section V, average about 1,500 to 2,000 mg/l of BOD5 and 1,500 to 3,500 mg/l of suspended solids. Flows from these mills are much smaller than from corn wet mills, averaging some 0.00045 to 0.0013 cu m/kkg (3 to 8 gal/MSBu).

Treatment in the industry is thought to be very limited, as most mills discharge to municipal systems. One known pretreatment plant is discussed in this section.

In-Plant Controls

Waste waters can arise from only three sources in corn dry mills, namely, car washing, corn washing and air scrubbers. Car washing is practiced infrequently and at only some mills and will not be considered further. Dry car cleaning techniques are now available using vacuum systems to replace wet methods. As mentioned in Section III, water is used in air scrubbers on expanders and extruders. Water from this source is excluded from consideration in the document as it is not part of the basic milling sequence.

Corn washing is performed by many, but not all, of the corn mills. Some mills, because of the condition of the corn as received or other factors, feel that wet washing is not necessary. At the mills where wet washing is practiced, little can be done in terms of in-plant control to improve the system. It is possible that some mills use more water than is required, but the total amounts of contaminants should remain constant. These contaminants reflect the nature of the corn as it is received and little can be done to reduce the total amounts. It is possible that partially clarified waste waters could be recycled into the corn washing operation, but this has not yet been demonstrated.

Waste Water Treatment

Only one plant is known to provide treatment for their process waste waters. The treatment sequence consists of settling to recover the heavy solids for animal feed, followed by a plastic media trickling filter and discharge to the municipal system. Sampling data secured at this treatment plant are summarized below:

	Average Influent mg/l	Average Effluent mg/l
BOD5	2,748	608
COD	4,901	2,983
Suspended Solids	3,485	1,313

Tests run on settled samples from this treatment plant indicated additional removals of about 50 percent of the BOD_5 and 70 percent of the suspended solids could be achieved by secondary clarification.

The results from this pretreatment plant clearly demonstrate that wastes from corn dry mills are amenable to conventional biological treatment. It is anticipated that treatment of these wastes will be somewhat less difficult than those from wet corn mills, inasmuch as lower volumes and perhaps less exotic constituents are involved. Specifically, it is anticipated that sludge bulking will be less of a problem with this type of waste water than with the very high carbohydrate waste waters from corn wet mills.

Sludge Disposal

The prevalent practice in the corn dry milling industry is to recover the heavier solids from the wash water for use in animal feed. If biological treatment of the waste waters is provided, it would appear that waste biological solids could also be incorporated into animal feed.

WHEAT MILLING

Ordinary wheat milling generates little in the way of process waste waters except from car washing and wheat washing. Both of these activities are not practiced at most mills and consideration will not be given to these waste waters in this section. Wet car and wheat washing systems presently in use can be replaced by dry cleaning systems.

The several plants that produce bulgur do generate limited quantities of waste water. In view of the rather small quantities of waste water, ranging from 38 to 114 cu m/day (10,000 to 30,000 gpd), it is not anticipated that the raw waste characteristics can be greatly influenced by in-plant controls. Observations at one bulgur mill, however, indicated that the quantities of waste water might be reduced by more careful operational control.

All of the bulgur producers presently discharge their wastes to minicipal systems and no treatment of such wastes is practiced in this country. The waste strength, however, indicates that it should be amenable to conventional biological treatment processes. The raw waste characteristics range from about 250 to 500 mg/l of BOD_5 and 300 to 400 mg/l of suspended solids. Effluent levels roughly equivalent to those achieved in well-operated secondary minicipal sewage treatment plants should be attainable.

RICE MILLING

Ordinary rice milling involves no process waters and, hence, generates no process waste waters. Six mills parboil rice, and this process does result in modest amounts of process waste waters. These waste waters are high in dissolved BOD, approximately 1,300 mg/l, but low in suspended solids, 30 to 80 mg/l.

The waste water comes from the steeping process, and in-plant controls cannot be effected that will influence appreciably the quantity or character of the waste waters. At least five of the six parboiled rice plants discharged their wastes to municipal systems and no known treatment is practiced by any mill. Once again, however, the general nature of the waste water indicates that it can be treated by biological processes in a similar manner to corn milling or bulgur production, inasmuch as the BOD_5 is largely in a soluble form. The rather constant character of the waste stream should make it more amenable to stable treatment plant operation than corn wet milling waste waters. Moreover, the waste water volumes, i.e., from 265 to 760 cu m/day (70,000 to 200,000 gpd) make the wastes much more manageable. It is possible that the biological solids from any treatment process could be included with the bran and hulls as animal feed.

SECTION VIII

COST, ENERGY, AND NON-WATER QUALITY ASPECTS

The following presents detailed cost estimates for the various treatment alternatives and the rationale used in developing this information.

Data have been developed for investment, capital, operating and maintenance, depreciation, and energy costs using various sources including information from individual grain mills, Sverdrup & Parcel files, and literature references 21 and 22. Generally, the cost data from industry relate to specific items of equipment and are of limited utility. Moreover, most of the treatment systems presently in use in the grain milling industry were built over a period of years and the cost data that is available is difficult to extrapolate and to relate to the proposed treatment alternatives. As a result, the cost estimates are based principally on data developed by the contractor and the references cited previously.

REPRESENTATIVE PLANTS

Because of the variations in plant opeation, waste water characteristics, and treatment systems, it was impractical to select one existing plant as typical of each of the grain milling subcategories. Therefore, hypothetical plants were developed (or synthesized) for purposes of developing cost data. Each of the synthesized plants was in the medium to moderately large production size range for the subcategory under consideration. Flow and waste water characteristics were selected to reflect average values for existing plants in the industry as reported in Section V.

TERMINOLOGY

Investment Costs

Investment costs are defined as the capital expenditures required to bring the treatment or control technology into operation. Included, as appropriate, are the costs of excavation, concrete, mechanical and electrical equipment installed, and piping. An amount equal to from 15 to 25 percent of the total of the above is added to cover engineering design services, construction supervision, and related costs. The lower figure is used for larger facilities. Because most of the control technologies involved external, end-of-plant systems, no cost is included for lost time due to installation. It is believed that the interruptions required for installation of control technologies can be coordinated with normal plant operating schedules. As noted above, the control facilities are estimated on the basis of minimal space requirements. Therefore, no additional land, and hence no cost, would be involved for this item.

Capital Costs

The capital costs are calculated, in all cases, as 8 percent of the total investment costs. Consultations with representatives of industry and the financial community lead to the conclusion that, with the limited data available, this estimate is reasonable for this industry.

Depreciation

Straight-line depreciation for 20 years, or 5 percent of the total investment cost, is used in all cases.

Operation and Maintenance Costs

Operation and maintenance costs include labor, materials, solid waste disposal, effluent monitoring, added administrative expense, taxes, and insurance. When the control technology involved water recycling, a credit of $0.30 per 1,000 gallons is applied to reduce the operation and maintenance costs. Manpower requirements are based upon information supplied by the representative plants as far as possible. A total salary cost of $10 per man-hour is used in all cases. The costs of chemicals used for maintenance and operation.

Energy and Power Costs

Power costs are estimated on the basis of $0.025 per kilowatt-hour.

COST INFORMATION

The investment and annual costs, as defined above, associated with the alternative waste treatment control technologies are presented in this section. In addition, a description of each of the control technologies is provided, together with the effluent quality expected from the application of these technologies. All costs are reported in terms of August, 1971 dollars.

Corn Wet Milling

As a basis for developing control and treatment cost information, a medium-sized corn wet mill, with a daily grind of 1524 kkg (60,000 SBu) was synthesized. This hypothetical plant practices good in-plant control and uses recirculated cooling water. The waste water characteristics from the mill reflect actual industry practice based on average data received from existing mills. These waste water characteristics are as follows:

Flow	11,355 cu m/day	(3.0 mgd)	
BOD5	7.14 kg/kkg	(400 lbs/MSBu)	960 mg/l
Suspended Solids	3.57	(200 lbs/MSBu)	480 mg/l

A number of alternative treatment systems are proposed to handle the waste waters from this hypothetical mill. The investment and annual cost information for each alternative, and the resultant effluent qualities are presented in Table 15. The specific treatment technologies are described in the following paragraphs.

Alternative A -- Activated Sludge

This alternative provides for grit removal, pH adjustment, nutrient addition, complete-mix activated sludge, secondary sedimentation, and centrifugation for solids dewatering. The treatment system does not include equalization or primary sedimentation. Effluent BOD5 and suspended solids concentrations are expected to be 150 to 250 mg/l for both parameters. In terms of raw material input, the effluent values correspond to 1.12 to 1.86 kg/kkg (63 to 104 lbs/ MSBu).

Costs. Investment costs of approximately $2,388,000.

Reduction Benefits. BOD5 and suspended solids reductions of about 80 and 58 percent respectively.

Alternative B -- Equalization and Activated Sludge

Alternative B includes 12 to 18 hours of aerated equalization ahead of the complete-mix activated sludge process and associated chemical feed, sedimentation, and sludge dewatering facilities proposed in Alternative A. Average effluent levels are estimated to be about 75 to 125 mg/l of both BOD5 and suspended solids. These concentrations correspond to 0.55 to 0.91 kg/kkg (31 to 52 lbs/ MSBu) for both parameters.

Two mills now provide the general type of treatment system proposed in this alternative. Another similar facility provides pretreatment for a third mill.

Costs. Incremental costs are approximately $156,000 over Alternative A for a total cost of $2,544,000.

TABLE 15

TYPICAL PLANT

WATER EFFLUENT TREATMENT COSTS

CORN WET MILLING

Treatment or Control Technologies Identified under Item III of the Scope of Work:	A	B	C	D	E	F	(Added Cost) G
Investment*	$2,388	$2,544	$2,832	$2,832	$4,076	$5,960	$+288
Annual Costs:*							
Capital Costs	191	203	227	227	326	477	+ 23
Depreciation	119	127	142	142	204	298	+ 14
Operating and Maintenance Costs (excluding energy and power costs)	181	186	191	230	312	770	+105
Energy and Power Costs	60	72	72	75	82	170	6
Total Annual Cost*	551	588	632	674	924	1715	148

*Costs in thousands of dollars

Effluent Quality:

Effluent Constituents Parameters	(Units)	Raw Waste Load	Resulting Effluent Levels						
BOD	kg/kkg	7.14	1.12-1.86	0.55-0.91	0.223-0.447	0.15-0.22	0.037	0.037	N/A
Suspended Solids	kg/kkg	3.57	1.12-1.86	0.55-0.91	0.223-0.447	0.07-0.15	0.037	0.037	N/A
BOD	mg/l	960	150-250	75-125	30-60	20-30	5	5	N/A
Suspended Solids	mg/l	480	150-250	75-125	30-60	10-20	5	5	N/A
Dissolved Solids	mg/l	-	-	-	-	-	-	500	

N/A - Not Applicable--Water conservation only

Reduction Benefits. BOD5 and suspended solids will be reduced by about 90 and 80 percent respectively.

Alternative C -- Equalization, Activated Sludge, and Stabilization Lagoon

For Alternative C, a stabilization basin following secondary sedimentation is added to the preceding treatment system. This stabilization lagoon will provide 10-day detention for stabilizing the remaining BOD5 and reducing suspended solids. One mill presently provides a version of this treatment sequence, but without equalization. Effluent concentrations of 30 to 60 mg/l of BOD5 and suspended solids are expected from Alternative C. The resultant effluent waste load will be 0.223 to 0.447 kg/kkg (12.5 to 25.0 lbs/MSBu) for both BOD5 and suspended solids.

Costs. Incremental costs of approximately $288,000 over Alternative B for a total cost of $2,832,000.

Reduction Benefits. BOD5 and suspended solids reductions of about 95 and 90 percent respectively.

Alternative D -- Equalization, Activated Sludge, and Deep Bed Filtration

In this proposed system, deep bed filtration is added to the activated sludge system presented as Alternative B. The stabilization basin of Alternative C has been deleted. A treatment system similar to Alternative D is now under construction. BOD5 and suspended solids concentrations of 20 to 30 mg/l and 10 to 20 mg/l respectively are expected in the effluent from this alternative. These concentrations correspond to effluent loads of 0.15 to 0.22 kg/kkg (8.3 to 12.5 lbs/MSBu) of BOD5 and 0.07 to 0.15 kg/kkg (4.2 to 8.3 lbs/MSBu) of suspended solids.

Costs. Incremental costs of approximately $288,000 over Alternative B for a total cost of $2,832,000, the same cost as Alternative C.

Reduction Benefits. BOD5 and suspended solids reductions of about 97.4 and 96.9 percent respectively.

Alternative E -- Equalization, Activated Sludge, Deep Bed Filtration and Activated Carbon Filtration

Activated carbon filtration is added to the activated sludge with the deep bed filtration system proposed as Alternative D. The effluent concentrations are estimated to be 5 mg/l for both BOD and suspended solids. This level corresponds to a waste load of 0.037 kg/kkg (2.1 lbs/MSBu) for both constituents. No treatment facility in the entire industry provides this level of treatment.

Costs. Incremental costs of approximately $1,244,000 over either Alternative C or D for a total cost of $4,076,000.

Reduction Benefits. BOD5 and suspended solids reduction of about 99.5 and 99.0 percent respectively. The effluent should be suitable for at least partial recycle.

Alternative F -- Equalization, Activated Sludge, Deep Bed Filtration, Activated Carbon Filtration, and Reverse Osmosis

This alternative includes reverse osmosis to reduce the total dissolved solids. Effluent levels will be comparable to those given in Alternative E, but with a maximum dissolved solids content of 500 mg/l.

Costs. Incremental costs of approximately $1,884,000 over Alternative E for a total cost of $5,960,000.

Reduction Benefits. BOD5 and suspended solids reductions equal to those in Alternative E, i.e., 99.5 and 99.0 percent respectively. The effluent should be suitable for complete recycle.

Alternative G -- Recirculating Cooling Water System

The synthesized corn wet mill described previously is assumed to have good in-plant water conservation practices including recirculating cooling water systems. Comparably sized mills using once-through cooling waters will be confronted with the additional cost of installing cooling towers to reduce total waste water flows. A separate cost has been developed for such plants based on a recirculating cooling water demand of about 34,000 cu m/day (9.0 mgd or 6250 gpm).

Cost. Incremental costs of adding a cooling tower are approximately $288,000.

Corn Dry Milling

A hypothetical corn dry mill of moderate to large size, i.e. 762 kkg/day (30,000 SBu/day), was selected as a basis for developing costs data. The investment and annual cost information for each alternative, and the resultant effluent qualities are presented in Table 16. This synthesized plant generates a waste water that reflects actual industry practice as follows:

Flow	492 cu m/day	(130,000 gpd)	
BOD5	1.13 kg/kkg	(63 lbs/MSBu)	1750 mg/l
Suspended Solids	1.61	(90 lbs/MSBu)	2500 mg/l

Alternative A -- Primary Sedimentation

This alternative consists only of primary sedimentation and reduces the BOD5 and suspended solids to about 1,000 mg/l and 500 mg/l respectively. These concentrations correspond to effluent waste loads of 0.65 kg/kkg (36 lbs/MSBu) of BOD5 and 0.32 kg/kkg (18 lbs/ MSBu) of suspended solids. Presumably some corn dry mills have clarifiers similar to that provided for Alternative A.

Cost. Investment costs of approximately $20,000.

Reduction Benefits. BOD5 and suspended solids reductions of about 43 and 80 percent respectively.

Alternative B -- Primary Sedimentation and Activated Sludge

Alternative B includes primary sedimentation, nutrient addition, complete-mix activated sludge, secondary sedimentation, and sludge dewatering. Expected effluent levels are 100 mg/l of BOD5 and suspended solids corresponding to a treated waste load of 0.065 kg/kkg (3.6 lbs/MSBu) for both pollutant parameters.

Costs. Incremental costs of approximately $271,000 over Alternative A for a total cost of $291,000.

Reduction Benefit. BOD5 and suspended solids reductions of about 94.3 and 96.0 percent respectively.

Alternative C -- Primary Sedimentation, Activated Sludge, and Stabilization Lagoon

This alternative adds a 10-day stabilization lagoon in series with the activated sludge system as given in Alternative B. Effluent quality is expected to be 30 to 60 mg/l of BOD5 and suspended solids or an effluent waste load of 0.019 to 0.039 kg/kkg (1.1 to 2.2 lbs/ MSBu) for both constituents.

Costs. Incremental costs of approximately $25,000 over Alternative B for a total cost of $316,000.

Reduction Benefit. BOD5 and suspended solids reductions of about 97.4 and 98.2 percent respectively.

TABLE 16

TYPICAL PLANT

WATER EFFLUENT TREATMENT COSTS

DRY CORN MILLING

Treatment or Control Technologies Identified under Item III of the Scope of Work:	A	B	C	D	E
Investment*	$20	$291	$315.6	$323.2	$497
Annual Costs:*					
Capital Costs	1.6	23	25.2	25.9	39.8
Depreciation	1.0	14.6	15.8	16.2	24.9
Operating and Maintenance Costs (excluding energy and power costs)	8.3	39.8	42.8	47.6	57.6
Energy and Power Costs	1.4	13	13	14.6	17.8
Total Annual Cost*	10.9	90.4	96.8	104.3	140.1

*Costs in thousands of dollars

Effluent Quality:

Effluent Constituents Parameters	(Units)	Raw Waste Load	Resulting Effluent Levels				
BOD	kg/kkg	1.13	0.65	0.065	0.019-0.039	0.013-0.019	0.003
Suspended Solids	kg/kkg	1.61	0.32	0.065	0.019-0.039	0.006-0.013	0.003
BOD	mg/l	1750	1000	100	30-60	20-30	5
Suspended Solids	mg/l	2500	500	100	30-60	10-20	5

Alternative D -- Primary Sedimentation, Activated Sludge, and Deep Bed Filtration

Deep bed filtration following the activated sludge system comprises this alternative. The concentration of BOD5 and suspended solids in the treated effluent is expected to be 20 to 30 mg/l and 10 to 20 mg/l respectively. These effluent concentrations are equivalent to waste loads of 0.013 to 0.019 kg/kkg (0.7 to 1.1 lbs/MSBu) of BOD5 and 0.006 to 0.013 kg/kkg (0.36 to 0.7 lbs/MSBu) of suspended solids.

Costs. Incremental costs of approximately $32,000 over Alternative B for a total cost of $323,000.

Reduction Benefit. BOD5 and suspended solids reductions of about 98.6 and 99.4 percent respectively.

Alternative E -- Primary Sedimentation, Activated Sludge, Deep Bed Filtration, and Activated Carbon Filtration

The final alternative presented herein adds acitvated carbon filtration to the activated sludge - deep bed filtration system of the previous alternative. Treated effluent quality is expected to be 5 mg/l of both BOD5 and suspended solids for an equivalent waste load of 0.003 kg/kkg (0.18 lbs/MSBu).

Costs. Incremental costs of $174,000 over Alternative D for a total cost of $497,000.

Reduction Benefit. BOD5 and suspended solids reductions of about 99.7 and 99.8 percent respectively

Wheat Milling (Bulgur)

Inasmuch as ordinary wheat milling usually generates no process waste waters, this discussion will be limited to bulgur production. The investment and annual cost information for each alternative, and the resultant effluent qualities are presented in Table 17. The synthesized bulgur mill is of medium size, 203 kkg/day (8000 Sbu/day) and discharges waste waters with the following characteristics:

Flow	56.7 cu m/day	(15,000 gpd)	
BOD5	0.104 kg/kkg	(6.25 lbs/MSBu)	400 mg/l
Suspended Solids	0.093 kg/kkg	(5.62 lbs/MSBu)	360 mg/l

Alternative A -- Activated Sludge

The first alternative provides an activated sludge (extended aeration) system with nutrient addition and secondary sedimentation. No primary sedimentation is provided because of the low flows. Moreover, it is anticipated that factory built or

TABLE 17

TYPICAL PLANT

WATER EFFLUENT TREATMENT COSTS

WHEAT (BULGAR) MILLING

Treatment or Control Technologies Identified under Item III of the Scope of Work:	A	B	C
Investment*	$24.2	$93.	$380
Annual Costs:*			
Capital Costs	2.0	7.4	30.4
Depreciation	1.2	4.7	19
Operating and Maintenance Costs (excluding energy and power costs)	6.7	12.7	20.5
Energy and Power Costs	2.5	3	4.5
Total Annual Cost*	11.4	27.8	74.4

*Costs in thousands of dollars

Effluent Quality:

Effluent Constituents Parameters	(Units)	Raw Waste Load	Resulting Effluent Levels		
BOD	kg/kkg	0.104	0.0078	0.0027-0.0052	0.0013
Suspended Solids	kg/kkg	0.093	0.0078	0.0013-0.0027	0.0013
BOD	mg/l	400	30	10-20	5
Suspended Solids	mg/l	360	30	5-10	5

so-called package treatment systems can be used. Sludge will be hauled away several times a year for land disposal. The treated effluent quality is expected to be 30 mg/l of both BOD5 and suspended solids corresponding to 0.0078 kg/kkg (0.47 lbs/MSBu).

Costs. Investment costs of approximately $24,000.

Reduction Benefit. BOD5 and suspended solids reductions of about 92.5 and 91.7 respectively.

Alternative B -- Activated Sludge and Deep Bed Filtration

This alternative adds deep bed filtration to activated sludge system. The filtered effluent is expected to contain 10 to 20 mg/l of BOD5 and 5 to 10 mg/l of suspended solids. The corresponding effluent waste loads are 0.0027 to 0.0052 kg/kkg (0.16 to 0.31 lbs/MSBu) of BOD5 and 0.0013 to 0.0027 kg/kkg (0.08 to 0.16 lbs/MSBu) of suspended solids.

Costs. Incremental costs of approximately $69,000 over Alternative A for a total cost of $93,000.

Reduction Benefit. BOD5 and suspended solids reductions of about 96.2 and 97.8 percent respectively.

Alternative C -- Activated Sludge, Deep Bed Filtration, and Activated Carbon Filtration

This final alternative incorporates activated carbon filtration as a final polishing step after Alternative B. The treatment effluent quality is expected to be 5 mg/l of both BOD5 and suspended solids or an effluent waste load of 0.0013 kg/kkg (0.08 lbs/MSBu).

Costs. Incremental costs of approximately $287,000 over Alternative B for a total cost of $380,000.

Reduction Benefit. BOD5 and suspended solids reductions of about 98.8 and 98.6 respectively.

Rice Milling (Parboiled Rice)

This discussion will be limited to parboiled rice milling since ordinary rice milling generates no process waste waters. The hypothetical rice mill selected for developing cost data is a moderately large plant processing 363 kg/day (8000 cwt/day). The investment and annual cost information for each alternative, and the resultant effluent qualities are presented in Table 18. Raw waste water characteristics are:

Flow	492 cu m/day	(130,000 gpd)
BOD5	1.88 kg/kkg	(0.188 lbs/cwt) 1380 mg/l
Suspended Solids	0.075 kg/kkg	(0.0075 lbs/cwt) 55 mg/l

TABLE 18

TYPICAL PLANT

WATER EFFLUENT TREATMENT COSTS

RICE MILLING

Treatment of Control Technologies Identified under Item III of the Scope of Work:	A	B	C	D
Investment*	$313	$348	$347	$528
Annual Costs:*				
Capital Costs	23	28	28	42.2
Depreciation	14.3	17.5	17.4	26.4
Operation and Maintenance Costs (excluding energy and power costs)	47.3	50	55.1	65
Energy and Power Costs	10	10	11	15
Total Annual Cost*	94.6	105.5	111.5	148.6

*Costs in thousands of dollars

Effluent Quality:

Effluent Constituents Parameters	(Units)	Raw Waste Load	Resulting Effluent Levels			
BOD	kg/kkg	1.88	0.14	0.041-0.081	0.027-0.041	0.007
Suspended Solids	kg/kkg	0.075	0.08-0.11	0.041-0.081	0.007-0.014	0.007
BOD	mg/l	1380	100	30-60	20-30	5
Suspended Solids	mg/l	55	60-80	30-60	5-10	5

Alternative A -- Activated Sludge

The first treatment alternative provides nutrient addition, complete mix activated sludge and secondary sedimentation. Waste activated sludge is dewatered by a centrifuge and mixed with the millfeed (animal feed). Treated waste water concentrations of 100 mg/l of BOD and 60 to 80 mg/l of suspended solids are expected. These effluent levels correspond to waste loads of 0.14 kg/kkg (0.014 lbs/cwt) of BOD5 and 0.08 to 0.11 kg/kkg (0.008 to 0.011 lbs/cwt) of suspended solids.

Costs. Investment costs of approximately $313,000.

Reduction Benefit. BOD5 reductions of about 92.8 percent.

Alternative B -- Activated Sludge and Stabilization Lagoon

This alternative merely adds a 10-day stabilization lagoon to the activated sludge system of Alternative A to effect greater BOD5 and suspended solids removals. The effluent quality from Alternative B is expected to be 30 to 60 mg/l of BOD5 and suspended solids or an equivalent waste load of 0.041 to 0.081 kg/kkg (0.004 to 0.008 lbs/cwt).

Costs. Incremental costs of approximately $35,000 over Alternative A for a total cost of $348,000.

Reduction Benefit. BOD5 reduction of about 96.7 percent.

Alternative C -- Activated Sludge and Deep Bed Filtration

Alternative C consists of the activated sludge system proposed in Alternative A followed by deep bed filtration. The concentrations of BOD5 and suspended solids in the effluent are expected to be 20 to 30 mg/l and 5 to 10 mg/l respectively. These concentrations correspond to effluent waste loads of 0.027 to 0.041 kg/kkg (0.0027 to 0.0041 lbs/cwt) of BOD5 and 0.007 to 0.014 kg/kkg (0.0007 to 0.0014 lbs/cwt) of suspended solids.

Costs. Incremental costs of approximately $34,000 over Alternative A for a total cost of $347,000.

Reduction Benefit. BOD5 and suspended solids reductions of about 98.2 and 86.4 percent respectively.

Alternative D -- Activated Sludge, Deep Bed Filtration, and Activated Carbon Filtration

In this last alternative, activated carbon is added to the activated sludge and deep bed filtration treatment system. Treated effluent quality is expected to be 5 mg/l of both BOD5 and suspended solids or an effluent waste load of 0.007 kg/kkg (0.0007 lbs/cwt).

Costs. Incremental costs of approximately $181,000 over Alternative C for a total cost of $528,000.

Reduction Benefit. BOD5 and suspended solids reductions of about 99.6 and 90.9 percent respectively.

NON-WATER QUALITY ASPECTS OF TREATMENT AND CONTROL TECHNOLOGIES

Air Pollution Control

With the proper operation of the types of biological treatment systems presented earlier in this section, no significant air pollution problems should develop. Since the waste waters from the grain milling industry have a high organic content, however, there is always the potential for odors. At least one present treatment plant has experienced rather severe odor problems from a sludge lagoon. Care should be taken in the selection, design, and operation of biological treatment systems to prevent anaerobic conditions and thereby eliminate possible odor problems.

Solid Waste Disposal

The treatment of grain milling waste waters will give rise to substantial quantities of solid wastes, particularly biological solids from activated sludge or comparable systems. Several avenues are available for the disposal of these solids including digestion and landfill, incineration, and other conventional methods fo handling biological solids. Alternately, the solids can be dewatered and added to the animal feed already being produced at these mills. This practice has found some acceptance in the grain milling industry, particulary in the corn wet milling segment, and is strongly recommended. Additional discussion of solids recovery and sludge disposal is contained in Section VII.

Energy Requirements

The treatment technologies presently in use or proposed in this document do not require any processes with unusually high energy requirements. Power will be required for aeration, pumping, centrifugation, and other unit operations. These requirements, generally are a direct function of the volume to be treated. Thus, the greatest requirements will be in the corn wet milling subcategory and the least in bulgur waste water treatment.

For the hypothetical treatment systems described previously in this section, the power requirements are in the range of 375 to 450 kw (500 to 600 hp). This level of demand is small relative to the requirements for the entire mill. Similar projections in the other grain milling subcategories lead to the conclusions that the energy needs for achieving good waste water treatment constitute only a small portion of the energy demands of the industry. These added demands can readily be accomodated.

SECTION IX

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE EFFLUENT LIMITATIONS GUIDELINES

INTRODUCTION

The effluent limitations that must be achieved July 1, 1977 are to specify the degree of effluent reduction attainable through the application of the best practicable control technology currently available. The best practicable control technology currently available is generally based upon the averages of the best existing performance by plants of various sizes, ages, and unit processes within the industrial category or subcategory. This average is not based on a broad range of plants within the grain milling industry, but on performance levels achieved by a combination of plants showing exemplary in-house performance and those with exemplary end-of-pipe control technology.

Consideration must also be given to:

a. The total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application;
b. the size and age of equipment and facilities involved;
c. the processes employed and product mix;
d. the engineering aspects of the application of various types of control techniques;
e. process changes; and
f. non-water quality environmental impact (including energy requirements).

Also, best practicable control technology currently available emphasizes treatment facilities at the end of a manufacturing process, but includes the control technologies within the process itself when the latter are considered to be normal practice within an industry. A further consideration is the degree of economic and engineering reliability which must be established for the technology to be "currently available." As a result of demonstration projects, pilot plants, and general use, there must exist a high degree of confidence in the engineering and economic practicability of the technology at the time of commencement of construction or installation of the control facilities.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Based on the information presented in Sections III through VIII of this report, it has been determined that the effluent reductions attainable through the application of the best practicable control technology currently available are those presented in Table 19. These values represent the maximum average allowable loading for any 30 consecutive calendar days. Excursions above these levels should be permitted with a maximum daily average of 3.0 times the average 30-day values listed below.

Table 19

Effluent Reduction Attainable Through the Application of Best Practicable Control Technology Currently Available*

Industry Category and Subcategory	BOD5 kg/kkg	BOD5 lbs/MSBu	Suspended Solids kg/kkg	Suspended Solids lbs/MSBu
Corn wet milling	0.893	50.0	0.893	50.0
Corn dry milling	0.071	4.0	0.062	3.5
Normal wheat flour milling	No discharge of process waste waters			
Bulgur wheat flour milling	0.0038	0.5	0.0083	0.5
Normal rice milling	No discharge of process waste waters			
Parboiled rice milling	0.140	0.014	0.080	0.008

(pH 6-9 all subcategories)

*Maximum average of daily values for any period of 30 consecutive days

IDENTIFICATION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

The best practicable control technology currently available for the grain milling industry generally consists of a high level of waste treatment coupled, in some instances, with certain in-plant modifications. The specific technological means available to implement the specified effluent limitations are presented below for each subcategory.

Corn Wet Milling

The corn wet milling segment of the grain milling industry must undertake major pollution abatement activities in order to meet the effluent limitations. These activities will include both in-plant modifications and biological waste water treatment as follows:

1. Isolating and collecting the major waste streams for treatment.
2. Eliminating once-through barometric cooling waters, especially from the steepwater and syrup evaporators. This change can be accomplished by recirculating these cooling waters over cooling towers or replacing the barometric

condensers with surface condensers.

3. Isolating once-through noncontact (uncontaminated) cooling waters for discharge directly to the receiving waters or provision of recirculating cooling tower systems with the blowdown directed to the treatment plant.

4. Diking of all process areas subject to frequent spills in order to retain lost product for possible reuse or by-product recovery.

5. Installing and maintaining modern entrainment separators in steepwater and syrup evaporators.

6. Monitoring the major waste streams to identify and control sources of heavy product losses.

7. Providing extensive waste treatment for the resulting process waste waters consisting of: flow and quality equalization, neutralization, biological treatment, and solids separation. The biological treatment methods available include activated sludge, pure oxygen activated sludge, bio-discs, and possible combinations of other biological systems.

Corn Dry Milling

Waste waters from corn dry mills are generated almost exclusively in corn washing. Little can be done to reduce the waste load from the plant and treatment of the entire waste stream will be necessary as follows:

1. Collection of waste waters from car washing operations, where practiced.

2. Primary solids separation by sedimentation.

3. Biological treatment using activated sludge or a comparable system.

4. Final separation of solids by sedimentation prior to discharge.

Wheat Milling

The effluent limitation for the milling of ordinary wheat flour permits no discharge of process wastes. Inasmuch as most ordinary wheat mills do not use process waters, this effluent limitation can be met with no plant changes. For the few mills that wash the wheat, dry cleaning systems are available to eliminate this waste source.

Bulgur wheat milling generates a relatively small quantity of process waste water that will require treatment to meet the effluent standards. Such treatment will include:

1. Primary solids separation by sedimentation.
2. Biological treatment using activated sludge or a comparable system.
3. Final separation of solids by sedimentation prior to discharge.

Rice Milling

Normal rice milling involves no process waters and, hence, the effluent limitation of no discharge of process wastes is already being met. The few mills producing parboiled rice generate a relatively small amount of high strength process waste water. The best practicable control technology currently available for the parboiled rice subcategory is as follows:

1. Biological treatment using activated sludge or comparable systems.
2. Final separation of solids by sedimentation prior to discharge.

RATIONALE FOR THE SELECTION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Corn Wet Milling

Cost of Application-

Data developed on the cost of applying various treatment technologies are presented in Section VIII. For a 1524 kkg (60,000 SBu) corn wet mill, the investment cost for implementing the best practicable control technology currently available is about $2,544,000, exclusive of the costs for in-plant control. Additional information on operating and maintenance costs is contained in Section VIII.

Age and Size of Production Facilities-

The mills in this subcategory range in age from two to over 60 years. The chronological age of the original buildings, however, does not accurately reflect the degree of modernization of the production facilities. In order to meet changing market demands and strong competition, most mills have actively developed new production techniques. As a result, it is difficult to differentiate between the basic production operations at the various plants based on age, except perhaps for the newest two or three mills.

Similarly, waste water characteristics from the corn wet mills cannot be classified according to plant age. While several of the newer mills generate low raw waste loads in terms of BOD_5 and suspended solids, at least one of the newer mills yields raw waste loads near the high end of the spectrum. Conversely, several older mills have low raw waste loads. The comparison of age versus raw waste load presented in Section V clearly demonstrates the absence of any correlation based on plant age. Accordingly, the age of the mill is not a direct factor in determining the best practicable control technology currently available. Indirectly, the age of the plant as it may be reflected in equipment layout may place some restraints on the ability of a particular plant to implement some recommended in-plant changes.

The size of the mill has a direct influence on the total amounts of contaminants discharged. In general, the larger the plant the greater the waste load. The effluent limitations presented herein have been developed in terms of unit of raw material input, i.e., kg/kkg or lbs/MSBu, in order to reflect the effect of plant size. The control technologies discussed in Section VII, however, are applicable to all mills regardless of size.

Production Processes-

The basic processes employed in corn wet mills are essentially uniform throughout this segment of the industry. From corn unloading through basic starch separation, the production methods are quite standard although slightly different types of equipment may be used at the various mills.

Product Mix-

The product mix at a given plant varies significantly on a monthly, weekly, and even daily basis. As a result, the raw waste characteristics at the plant may vary widely. Certain highly modified starches, for example, will result in higher waste loads per unit of raw material. In spite of the recognized influence of product mix on the raw waste characteristics of a given plant, no relationship between the raw waste characteristics from all the mills and their product mix can be distinguished based on available data, as previously discussed in Section V.

Thus, while consideration was given to the variability of the raw waste characteristics in developing the specified effluent limitations, this variability could not be quantitatively defined in terms of product mix. Moreover, there is no evidence to suggest that waste waters from any specific process so affect the character of the total plant waste stream as to substantially reduce the ability of the mill to implement the best practical control technology currently available.

Engineering Aspects of Application-

The engineering feasibility of achieving the effluent limitations using the technology discussed has been examined. Each of the in-plant and treatment control technologies presented are being used by one or more corn wet mills, although not necessarily in combination. Furthermore, each of these control steps effectively reduces the waste volume or the total waste load, or improves the quality of the treated effluent. Several of the control measures result in the isolation and resultant concentration of the process wastes into a smaller volume suitable for more economical treatment. Such practices have been in effect in a number of mills for several years. Once-through barometric cooling waters are of particular importance in this regard because they represent a high volume waste with low concentrations of pollutant constituents.

In-plant housekeeping and good operation can have a major impact on the raw waste loads from a mill. Diking of spill areas, monitoring, and careful operation have been reported to reduce raw waste loads by 25 to 50 percent in some plants.

Treatment of corn wet milling wastes with activated sludge and other biological systems has been demonstrated at seven mills as detailed in Section VII. Although treatment plant upsets do occur, a properly designed and operated system should be able to meet the effluent limitations developed in this document. At least one mill presently meets these effluent limitations using an activated sludge system followed by aerated lagoons. While this system includes one additional treatment step, the plant does not presently recirculate all barometric cooling water, a suggested control procedure.

The combination of in-plant controls and proper waste treatment constitutes a practicable means for achieving the specific effluent limitations. On an overall industry basis, these effluent limitations will result in a BOD5 reduction of approximately 85 to 90 percent and 85 percent reduction of suspended solids.

The concentrations of contaminants in the waste waters from plants using once-through barometric cooling water are in the moderate strength range, i.e., approximately 250 to 450 mg/l of BOD5 and 100 to 400 mg/l of suspended solids, as shown in Table 10. These wastes are generally slightly stronger than normal domestic sewage, but the secondary effluent limitations that have been established for municipal plants should be achievable by the proper treatment of these wastes. In establishing the effluent reduction attainable, as presented in Table 19, therefore, an effluent level of 30 mg/l of both suspended solids and BOD5 was selected for the plants using once-through contaminated cooling water. The levels established in Table 19 are equivalent to estimated effluent concentrations of 20 to 30 mg/l for such plants.

Many plants isolate the major process water sources and use recirculated cooling water systems. The effluent waste concentrations, therefore, are much higher than for those plant using once-through contaminated cooling waters. Raw wastes from these plants contain from 600 to 4500 mg/l of BOD5 and 300 to 2500 mg/l of suspended solids. The best practicable control technology currently available will effect approximately an 85 to 90 percent reduction in BOD5 and suspended solids for these concentrated wastes. Effluent concentrations of 100 mg/l of BOD5 and suspended solids are selected as general goals to be achieved by the effluent limitation guidelines. The 30 mg/l goal that was applied to dilute corn wet milling wastes cannot be achieved by the proposed technologies for these highly concentrated waste streams. The effluent limitation guidelines in Table 20 will result in estimated effluent concentrations of 50 to 200 mg/l of BOD5 and suspended solids. The higher values of these ranges are generally for new plants that practice maximum water recycling and produce highly concentrated waste steams of 3000 mg/l or higher.

Based on present waste water volumes in the industry, therefore, the average treated effluent resulting from these effluent limitations will contain about 50 mg/l of BOD. For those plants presently using once-through barometric cooling water, the effluent quality based on the present total waste water flow will be on the order of 20 to 30 mg/l of BOD. For those mills that utilize recirculating cooling water systems and have concentrated raw waste streams, the effluent limitations will require an effluent quality of approximately 100 mg/l of BOD5 and suspended solids.

Process Changes

The application of this control technology may require modifications to certain process equipment, but the basic process will remain unchanged. Some of the in-plant control measures have already been implemented at some mills.

Non-Water Quality Environmental Impact-

In terms of the non-water quality environmental impact, the only item of possible concern is the increased energy consumption to operate the treatment plant. Relative to the production plant energy needs, this added load is small and not of significant impact. For example, the power requirements for the application of the best practicable control technology currently available to a medium sized corn wet mill are estimated to be 450 kilowatts (600 hp). This demand represents a small percentage of the mill's total power usage.

Corn Dry Milling

Cost of Application-

The investment costs for implementing various control technologies were presented in Section VII. These costs were estimated for a moderately large corn dry mill to be $291,000.

Plant Age, Size and Production Methods-

The only source of process waste waters in corn dry mills is the washing operation (water from air scrubbers on extruders and expanders are not covered by these guidelines). Some mills do not wash the incoming corn, apparently reflecting a cleaner raw material or, possibly, less stringent quality control practices. Based on the limited data available, no correlation can be established between the raw waste characteristics and such factors as plant age, size, or production methods. Equally important, these factors do not affect the ability to apply the control technologies presented earlier in the section.

Engineering Aspects of Application-

Few, if any, corn dry mills provide extensive waste water treatment with discharge directly to the receiving waters. The best practicable control technology currently available does not represent practice achieved by any corn dry mill. Rather, this technology reflects the transfer of treatment practice demonstrated on other high strength food processing wastes. Data from one pretreatment plant clearly show that this type of waste water is amenable to biological treatment and suspended solids removal. Accordingly, the treatment technology recommended is considered to be quite practicable. The raw waste characteristics for corn dry mills indicated a BOD_5 of 600 to 2700 mg/l and a suspended solids level of 1000 to 3500 mg/l, as shown in Table 12. The best practicable control technology currently available will provide approximately 90 percent reduction of the strength of these wastes. An effluent concentration of about 100 mg/l for both BOD_5 and suspended solids was considered a practical goal and was used in developing the data given in Table 19. Estimated average effluent levels achievable, using the proposed effluent limitation guidelines, are about 105 mg/l of BOD_5 and 90 mg/l of suspended solids. Based on limited data for existing plants, the BOD_5 is expected to be between 80 and 150 mg/l, and suspended solids, between 70 and 115 mg/l. The treatment achieved represents 90 to 95 percent removal of both BOD_5 and suspended solids. Activated sludge or comparable biological treatment will achieve about 90 to 95 percent BOD_5 and suspended solids reductions. The final effluent concentrations to be realized by applying the specified control technologies will be about 100 mg/l of BOD_5 and suspended solids.

Non-Water Quality Environmental Impact-

The non-water quality environmental impact is restricted to the increased power consumption required for the treatment facility. This power consumption is quite small compared to the total energy requirements for a corn dry mill and, therefore, the impact of the control facilities is considered insignificant.

Wheat Milling

The only process waste water in wheat milling arises from the tempering operations used in bulgur flour production. No correlation can be established between the raw waste characteristics or ability to apply the specified control technologies and such factors as plant age or size, production methods, and raw material quality. No bulgur mill is known to provide waste water treatment at this time. The treatment technology defined previously, however, represents practice in related areas of food processing. Waste water from bulgur production should be amenable to solids separation and biological treatment. The waste strength is somewhat higher than normal sanitary sewage, but well below the high levels common in the other milling categories. As a result, treatment to effluent levels of about 30 mg/l of BOD5 and suspended solids is practicable and will be achieved by the effluent limitations presented in Table 19. Approximately 90 percent BOD5 and suspended solids reductions will result. The investment costs to provide the best practicable control for a medium sized bulgur plant were estimated in Section VIII to be $24,000.

Non-water quality environmental impact will be restricted to a small increase in power consumption for the treatment plant. These power needs are minimal and not of major significance.

Rice Milling

Waste waters from the production of parboiled rice represent the only source of process waste waters in rice milling. The characteristics of this high-strength soluble BOD5 waste cannot be related to plant age or size, production methods, or raw material quality. Likewise, the applicability of the specified control technologies is not dependent on any of these factors.

At present, no rice mill in the country provides waste water treatment. The best practicable control technology currently available, therefore, represents the transfer of treatment practice from other food processing industries. Pilot plant studies have demonstrated that the waste is amenable to biological waste treatment. Raw wastes from parboiled rice milling contain a high level of BOD, approximately 1,300 mg/l, as shown in Table 14, but a low level of suspended solids. Treatment of these wastes, using the best practicable control technology currently available, will achieve about a 90 to 95 percent reduction of BOD. Once again, an effluent BOD5 concentration of 100 mg/l was selected as a practical goal. The suspended solids level that has been specified, represents about 80 mg/l, almost all of which represent biological solids produced in the activated sludge system. Thus, the effluent suspended solids show no appreciable decrease, although their character has changed through the biological treatment sequence. In essence, the effluent suspended solids level is dictated by the type of treatment technology applied as opposed to the influent suspended solids levels. Estimated effluent BOD5 levels for two plants are 80 to 130 mg/l with suspended solids levels of 50 to 75 mg/l. The effluent limitations given in Table 19 will achieve about 90 to 95 percent BOD5 reductions and result in a treated waste water containing about 100 mg/l of BOD5 and 80 mg/l of suspended solids. As presented in Section VIII, the investment cost to provide this level of control for a moderately large plant will be about $313,000.

Non-water quality environmental impact will be restricted to a small increase in power consumption to operate the treatment plant.

RESTRAINTS ON THE USE OF EFFLUENT LIMITATIONS GUIDELINES

The effluent limitation guidelines presented above can generally be applied to all plants in each grain milling category. Special circumstances in individual plants, however, may warrant careful evaluation, especially in corn wet milling.

Corn wet mills are, by their very nature, sophisticated chemical plants producing a variety of products. Raw waste characteristics are dependent on many factors, not the least of which is product mix. It must be emphasized that, even with the implementation of the in-plant controls detailed earlier in this section, some plants will not be able to reduce their raw waste loads per unit of raw material input to the same low levels achieved by other mills.

Isolating all major process waste streams in some of the older plants may be very difficult and expensive. A similar situation may exist in the case of sanitary sewers. The discharge of sanitary wastes to the treatment plant will not adversely affect the treatment process, but it will eliminate the possibility of using waste solids from the treatment plant in feed preparations. Alternative solids disposal methods will have to be selected in such cases.

Conversion of barometric condensers to surface condensers is suggested as one means of concentrating waste streams, but such conversion is not without some problems. Specifically, surface condensers are more expensive than barometric units and they require considerably more maintenance. In some plants, existing equipment layouts prohibit conversion to surface condensers. Some mills have found that recirculation of barometric cooling waters over cooling towers can be readily accomplished and provide results that are comparable in terms of pollutant constituent levels in the waste stream.

Finally, it must be recognized that the treatment of high strength carbohydrate wastes is difficult. Upset conditions may occur that result in higher BOD5 and suspended solids discharges than normal. While the in-plant modifications and controls and the treatment sequence defined as best practicable control technology currently available will minimize these upsets, they may still occur. However, the limitation described above make adequate allowances for this possibility. The maximum daily average is three times the maximum allowable 30-day limitation for both BOD5 and suspended solids. However, the limitations described above make adequate allowances for this possibility. The maximum daily average is three times the maximum allowable 30 day limitations for both BOD5 and suspended solids.

SECTION X

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE EFFLUENT LIMITATIONS GUIDELINES

INTRODUCTION

The effluent limitations that must be achieved July 1, 1983 are to specify the degree of effluent reduction attainable through the application of the best available technology economically achievable. This control technology is not based upon an average of the best performance within an industrial category, but is determined by identifying the very best control and treatment technology employed by a specific plant within the industrial category or subcategory, or readily transferable from one industry process to another.

Consideration must also be given to:

a. The total cost of application of this control technology in relation to the effluent reduction benefits to be achieved from such application;
b. the size and age of equipment and facilities involved;
c. the processes employed;
d. the engineering aspects of the application of this control technology;
e. process changes; and
f. non-water quality environmental impact (including energy requirements).

Best available technology economically achievable, also, considers the availability of in-process controls as well as end-of-process control and additional treatment techniques. This control technology is the highest degree that has been achieved or has been demonstrated to be capable of being designed for plant scale operation up to and including "no discharge" of pollutants.

Although economic factors are considered in this development, the costs for this level of control are intended to be the top-of-the- line of current technology subject to limitations imposed by economic and engineering feasibility. However, this control technology may be characterized by some technical risk with respect to performance and with respect to certainty of costs. Therefore, this control technology may necessitate some industrially sponsored development work prior to its application.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

Based on the information contained in Sections III through VIII of this document, it has been determined that the effluent reductions attainable through the application of the best available technology economically achievable are those presented in Table 20. These values represent the maximum average allowable loading for any 30 consecutive calendar days. Excursions above these levels should be permitted with a maximum daily average of 3.0 times the average 30-day values listed below.

Table 20

Effluent Reduction Attainable Through the Application of Best Available Technology Economically Achievable*

Industry	BOD5		Suspended Solids	
subcategory	kg/kkg	lbs/MSBu	kg/kkg	lbs/MSBu
Corn wet milling	0.357	20	0.179	10
Corn dry milling	0.0357	2.0	0.0179	1.0
Normal wheat flour milling	No discharge of process waste waters			
Bulgur wheat flour milling	0.0050	0.3	0.0033	0.2
Normal rice milling	No discharge of process waste waters			
Parboiled rice milling	0.070	0.007	0.030	0.003

(pH 6-9 all subcategories)

*Maximum average of daily values for any period of 30 consecutive days

IDENTIFICATION OF BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

For all of the segments of the grain milling industry, the best available technology economically achievable comprises improved solids separation following activated sludge or comparable biological treatment. Improved solids separation can be represented best by deep bed filtration although alternative systems may be available. It is anticipated that the technology of removing biological solids by filtration will improve rapidly with the increased use of such treatment processes in many industries and municipalities.

In the corn wet milling subcategory, a combination of end-of-process treatment, as described above, and in-plant controls will be necessary to meet these effluent limitations. All of the in-plant controls presented in Section IX will have to be implemented, and additional controls instituted as follows:

1. Isolate and treat all process waste waters. No process wastes should be discharged without treatment.

2. Institute maximum water reuse at all plants over and above the current levels of practice.

3. Provide improved solids recovery at individual waste sources.

RATIONALE FOR THE SELECTION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

Corn Wet Milling

Cost of Application-

As presented in Section VIII, the investment cost for providing the best available technology economically achievable for a treatment plant serving a hypothetical medium-sized corn wet mill is $2,832,000. This cost is exclusive of any expenditures for in-plant controls. Detailed information on operating, maintenance, power, and other costs is contained in Section VIII.

Age, Size, and Type of Production Facilities-

As discussed in Section IX, differences in age or size of production facilities in the wet corn milling subcategory will not significantly affect the application of the best available technology economically achievable. Likewise, the production methods employed by the different mills are similar and will not influence the applicability of this same technology.

Engineering Aspects of Application-

The control technologies specified herein have not been fully demonstrated in any segment of the grain milling industry. The basic treatment processes, however, namely activated sludge and deep bed filtration, have been used in industrial and municipal applications in recent years to provide a high quality effluent. One corn wet milling company is currently installing such a system. This treatment plant should demonstrate the applicability of this level of technology to grain milling wastes.

In developing the effluent limitation guidelines attainable using the best available technology economically achievable, it was concluded that end-of-process treatment could effect an additional $BOD\underline{5}$ and suspended solids removal of 50 to 70 percent, compared to the levels achieved by the best practicable control technology currently available. Deep bed filtration will remove most of the remaining suspended solids following secondary clarification. In so doing, experience has shown that over 50 percent of the remaining BOD is normally associated with these suspended solids and is therefore removed.

For the dilute waste waters from plants using once-through contact cooling water, effluent concentrations of 10 mg/l of BOD5 and suspended solids should be achieved. For those plants using recirculated cooling water, effluent concentrations of from 30 to 50 mg/l can be accomplished by application of this level of treatment.

It is recognized that the soluble BOD5 level in some of the plants that generate concentrated waste streams may not permit attainment of BOD5 levels represented by the values in Table 20, using only end-of-process treatment. It is expected that the in-plant control measures that have been recommended will reduce the net raw waste loads sufficiently to permit attaining the effluent limitations as proposed. Each of the in-plant control measures is practiced by one or more plants, although not necessarily at the same plant. Thus, the in-plant control technology is available, although its application may be restricted in certain mills.

In summary, the combined effect of the application of the best available technology economically achievable and application of all practicable in-plant control measures should permit the corn wet mills to meet the effluent levels presented in Table 20.

Process Changes-

No basic process changes will be necessary to implement these control technologies. In fact, many of the in-plant modifications have already been made by some corn wet mills.

Non-Water Quality Environmental Aspects-

The application of the best available technology economically achievable will not create any new sources of air or land pollution, or require significantly more energy than the best practicable control technology currently available. Power needs for this level of treatment technology were estimated to be about 225 kw (625 hp) for the model plant developed in Section VIII. This demand is small when compared to the total production plant power requirements.

Corn Dry Milling

The cost of applying the best available technology economically achievable, defined above to a moderately large mill, has been estimated in Section VIII to be $323,000. Data on operating, maintenance, and power costs are presented in Section VIII.

The application of this control technology is not dependent upon the size or age of mill. As discussed under corn wet mills, the treatment technology has not been demonstrated in the grain milling industry, but is transferable from other waste treatment applications. Power requirements for the prescribed treatment system are small compared to the overall production demands. Other environmental considerations will not be affected by the application of this control technology.

Wheat Milling (Bulgur)

The best available technology economically achievable can be applied to a medium-sized bulgur mill for an investment cost of about $93,000. Other cost information is contained in Section VIII.

Plant size and age and other production factors will not influence the applicability of the suggested control technology. Experience in other waste treatment applications amply demonstrate the technical feasibility of the control system. Energy, air pollution, noise, and other environmental considerations have been evaluated and will not be significantly affected by the application of this technology.

Rice Milling (Parboiled Rice)

Application of the specified best available control technology economically achievable to a medium-sized parboiled rice plant is estimated to cost $347,000. Section VIII contains additional information on operating, maintenance, and energy costs.

Once again, the prescribed control technology has been demonstrated in related waste treatment applications. Energy needs are small compared to the production power demands. Other environmental factors, such as noise and air pollution, will be little affected by the application of this control technology.

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

INTRODUCTION

Standards of performance are presented in this section for new sources. The term "new source" is defined to mean "any source, the construction of which is commenced after the publication of the proposed regulations prescribing a standard of performance." These standards of performance are to reflect higher levels of pollution control that may be available through the application of improved production processes and/or treatment techniques.

Consideration should be given to the following factors:

a. The type of process employed and process changes;
b. operating methods and in-plant controls;
c. batch as opposed to continuous operations;
d. use of alternative raw materials;
e. use of dry rather than wet processes; and
f. recovery of pollutant as by-products.

The new source performance standards represent the best in-plant and end-of-process control technology coupled with the use of new and/or improved production processes. In the development of these performance standards, consideration must be given to the practicability of a standard permitting "no discharge" of pollutants.

NEW SOURCE PERFORMANCE STANDARDS

The performance standards for new sources in the grain milling industry are identical to the effluent limitations prescribed as attainable through the application of the best available technology economically achievable as presented in Section X. These new source performance standards are given in Table 21.

These values represent the maximum average allowable loading for any 30 consecutive calendar days. Excursions above these levels should be permitted with a maximum daily average of 3.0 times the average 30-day values listed below.

At the present time, a "no discharge" standard is not deemed practicable. It is anticipated that continued advancement in end-of-process treatment methods and in-plant control measures will result in future revisions in the new source performance standards.

Table 21

New Source Performance Standards*

Industry subcategory	BOD5 kg/kkg	BOD5 lbs/MSBu	Suspended Solids kg/kkg	Suspended Solids lbs/MSBu
Corn wet milling	0.357	20	0.179	10
Corn dry milling	0.0357	2.0	0.0179	1.0
Normal wheat flour milling	No discharge of process waste waters			
Bulgur wheat flour milling	0.0050	0.3	0.0033	0.2
Normal rice milling	No discharge of process waste waters			
Parboiled rice milling	0.070	0.007	0.030	0.003

(pH 6-9 all subcategories)

*Maximum average of daily values for any period of 30 consecutive days

RATIONALE FOR THE SELECTION OF NEW SOURCE PERFORMANCE STANDARDS

Corn Wet Milling

The specific control technologies to meet the new source performance standards are not presented in this document. It has been a basic premise, however, that all of the in-plant controls discussed in Section VII would be incorporated in a new mill. In addition, the end-of-process treatment system is to be equivalent to that suggested for the best control technology economically achievable. Recognizing that this level of waste water treatment has not been demonstrated in the grain milling industry, it is nonetheless felt that the combined effect of complete in-plant controls and the new treatment technology will meet the new source performance standards. Factors considered in developing these standards are summarized in the following paragraphs.

Production Process-

The basic production process used in corn wet milling cannot be significantly altered. The industry has historically been very aggressive in developing and utilizing new production technology. While new plants will undoubtedly incorporate some new or improved types of equipment, the basic process will remain largely in its present form for the foreseeable future.

Operating Methods and In-Plant Controls-

New plants offer the possibility of instituting better operating methods and in-plant controls. Without the physical constraints of existing facilities, essentially all of the in-plant controls discussed in Section VII can be implemented. Instrumentation is also available to improve plant operation and reduce accidental waste discharges. Greatly reduced waste loads should be attainable by these and other in-plant improvements.

Engineering Aspects of Application-

The control technology recommended to achieve new source performance standards is equivalent to that represented by the best available technology economically achievalble, namely an activated sludge system followed by deep bed filtration. Inasmuch as this type of treatment has not been specifically applied to corn wet milling wastes, initial operating experience with such systems may not fully meet the expected 50 to 75 percent BOD_5 and suspended solids removals form the secondary clarifier effluent. The application of complete in-plant controls and the use of good operating methods in new plants should significantly reduce the raw waste loads from these facilities. Accordingly, the effluent reductions specified by the proposed new source performance standards should be achievable for all new plants. As experience is gained with the end-of-process treatment, particularly the removal of suspended materials by filtration, it may be possible to reduce the new source performance standards, as given in Table 21. At the present time, however, these standards represent the best engineering judgment of those levels that would be achievable for new sources.

Changes in Unit Operations-

As stated above, the basic corn wet milling process is likely to remain unchanged for the immediate future. Minor modifications in unit operations are continually being made in this industry subcategory, but no additional improvements that would have a major impact on the waste water discharges have been developed.

By-Product Recovery-

By-product recovery has long been practiced in corn wet mills. Application of the best in-plant controls will undoubtedly increase by-product recovery, but will probably offer no new recovery avenues.

Corn Dry Milling

The new source standards for corn dry mills are based on the application of the best available technology economically achievable as represented by a high level of end-of-process treatment. Corn washing, the one source of process waste waters, is considered to be essential by many mills. Although some mills only dry clean the corn, many other companies believe that washing is necessary to control microbiological contamination and product quality. Depending on raw material quality and technical food product considerations, it is expected that most new mills will require corn washing.

Barring a total changeover to dry cleaning methods, little can be accomplished in reducing total plant waste loads. In-plant controls and operating methods may reduce total flows, but will not appreciably affect the total quantities of contaminants.

Wheat Milling (Bulgur)

The effluent levels to be achieved under the new source performance standards for bulgur production also reflect the application of the best available end-of-process technology as described in Section X. The basic production process requires water for soaking (or cooking) and this single source of process waste water cannot be eliminated. Operating methods, in-plant controls, and by-product recovery will not influence process waste loads except perhaps in terms of quantity of waste water. Some by-product recovery, i.e., the use of biological treatment solids in animal feeds, may result from the application of the prescribed treatment technology.

Rice Milling (Parboiled Rice)

Process waste waters in parboiled rice production originate from the steeping operation. This unit operation is integral to the basic parboiling process and cannot be eliminated or changed significantly. Likewise, in-plant controls and operating methods can reduce the total waste water flow in some instances, but not the total amount of pollutants. The new source standards of performance, therefore, provide for the application of the best available technology economically achievable as described in Section X. Recovery of biological solids from the treatment system for use in animal feed is envisioned.

SECTION XII

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SECTION XIV

GLOSSARY

1. <u>Aspirators</u>

Milling machine equipment that separates loosened hulls from the grain.

2. <u>Bran, Rice</u>

The pericarp or outer cuticle layers and germ of the rice grain.

3. <u>Bran, Wheat</u>

The several-layered covering beneath the wheat husk that protects the kernel.

4. <u>Brown Rice</u>

Rice from which the hull only has been removed, still retaining the bran layers and most of the germ. (Rice Millers Association, 1967.)

5. <u>Bulgur</u>

Wheat which has been parboiled, dried and partially debranned for later use in either cracked or whole grain form. (Wheat Flour Institute, 1965.)

6. <u>Corn Starch</u>

Substance obtained from corn endosperm and remaining after the removal of the gluten.

7. <u>Corn Syrup</u>

Produced by partial hydrolysis of the corn starch slurry through the aid of cooking, acidification and/or enzymes.

8. <u>Dextrose</u>

Corn sweetener created by completely hydrolyzing the corn starch slurry through the aid of cooking, acidifying and enzyme action.

9. <u>Endosperm</u>

The starchy part of the grain kernel.

10. <u>Germ</u>

The young embryo common to grain kernels (e.g., corn, wheat).

11. Gluten

High protein substance found in the endosperm of corn and wheat grain.

12. Hulls

The outer covering of the corn and rice kernel. The rice hull is normally called the lemma.

13. Middlings

Fractured wheat kernels resulting from the milling operations.

14. Modified Starch

A form of corn starch whose characteristics are developed by chemically treating raw starch slurry under controlled conditions.

15. Parboiled Rice

Rice which has been treated prior to milling by a technical process that gelantinizes the starches in the grain. (Rice Millers Association, 1967).

16. Pearlers (Whitener, Huller)

Rice milling machine equipment employed to remove the coarse outer layer of bran from the germ.

17. Rice Polish

The aleurone or inner cuticle layers of the rice kernel, containing only such amounts of the outer layers and of the starchy kernel as are unavoidable in the milling operation.

18. Steepwater

The water in which wet-miller corn is soaked before preparation.

METRIC UNITS
CONVERSION TABLE

MULTIPLY (ENGLISH UNITS)		by	TO OBTAIN (METRIC UNITS)	
ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram-calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories/ kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	°F	0.555 (°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	kilowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig +1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
tons (short)	ton	0.907	kkg	metric tons (1000 kilograms)
yard	yd	0.9144	m	meters

*Actual conversion, not a multiplier

pounds/hundred weight	cwt	10.0		kilograms/metric ton
standard bushel, corn (56 lbs)	SBu	25.4		kilograms
standard bushel, wheat (60 lbs)	SBu	27.2		kilograms

*U.S. GOVERNMENT PRINTING OFFICE: 1974 546-319/390 1-3